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Title: Selected Field Measurement Topics

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Selected Field Measurement Topics

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LA-UR-20-XXXXX

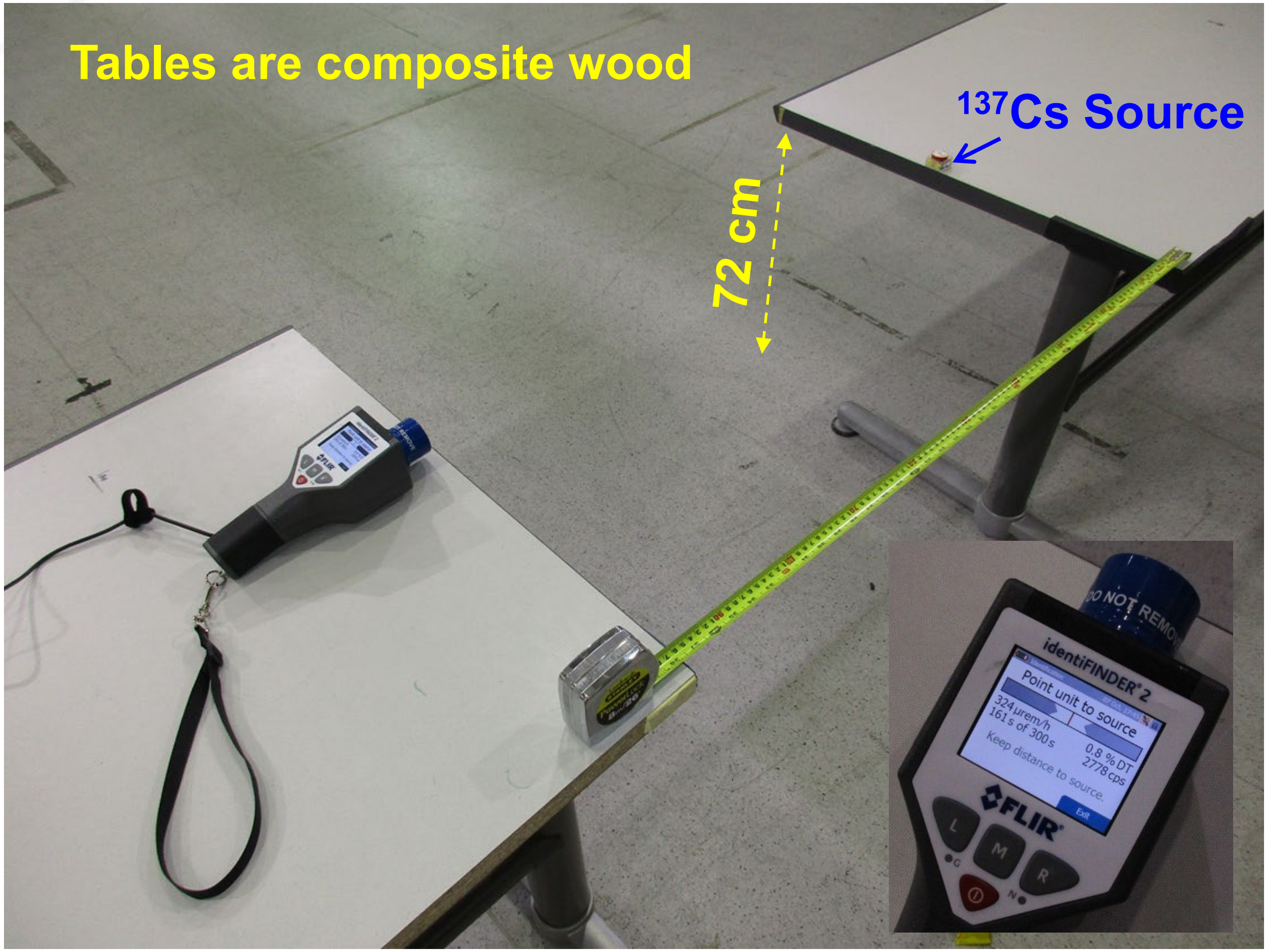
Introduction

- Various measurements were conducted with a NaI FLIR IdentiFINDER2 to examine the effects of:
  - The radiation scattering environment
  - Hotspot misalignment effects
  - Dead time
  - INL Coin
  - Neutrons
  - Thermal variations
- This brief study is by no means conclusive but it offers examples of how the conditions of the measurement can affect the result.

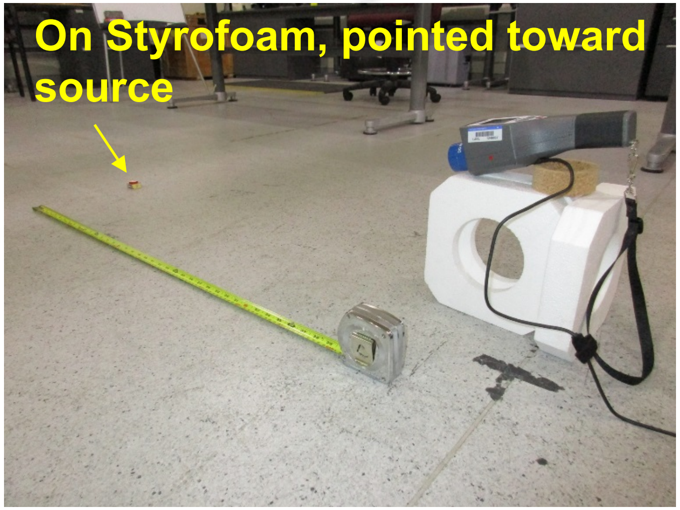
Scattering Study

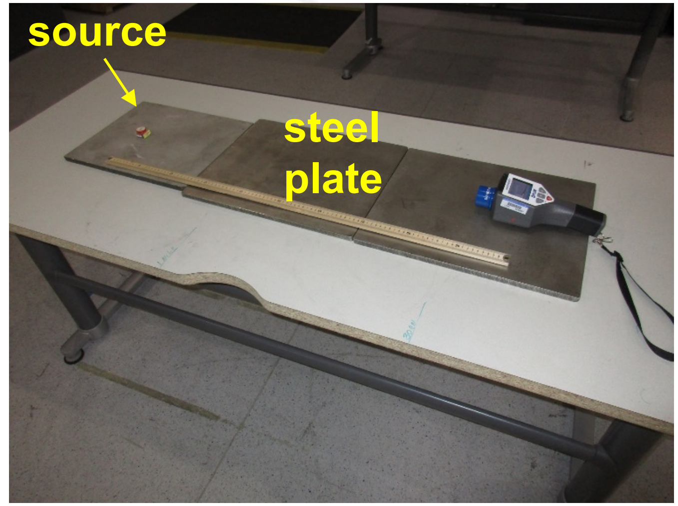
- The first experiment involves studying the effect of placing the identiFINDER on the ground to measure a source.
- A ‘baseline’ measurement was conducted with the detector and source both on tables
- Then several different measurement configurations were tested.

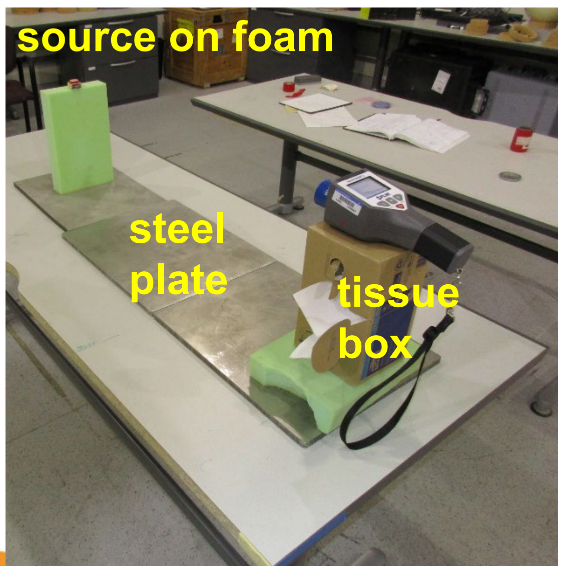
Baseline Measurement

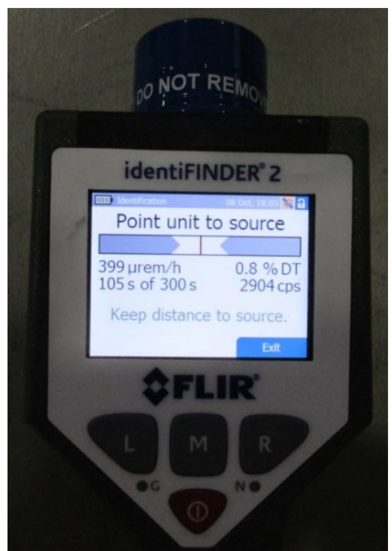


Other Configurations



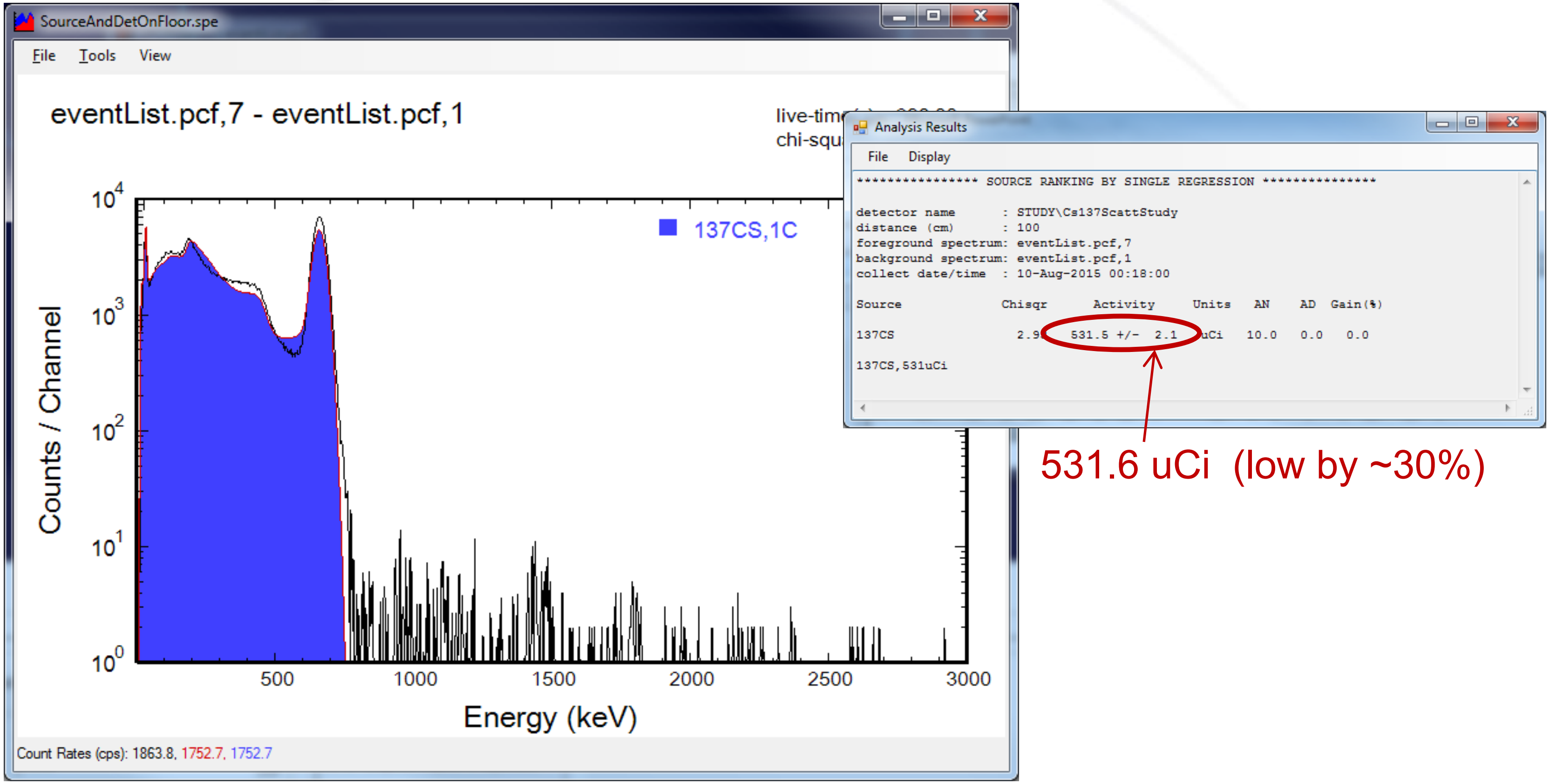






Distance was properly measured and detector was ‘in the carets’ for each configuration.

GADRAS Activity Calculation



For all cases the estimated activity was ~20 – 30 % lower than actual

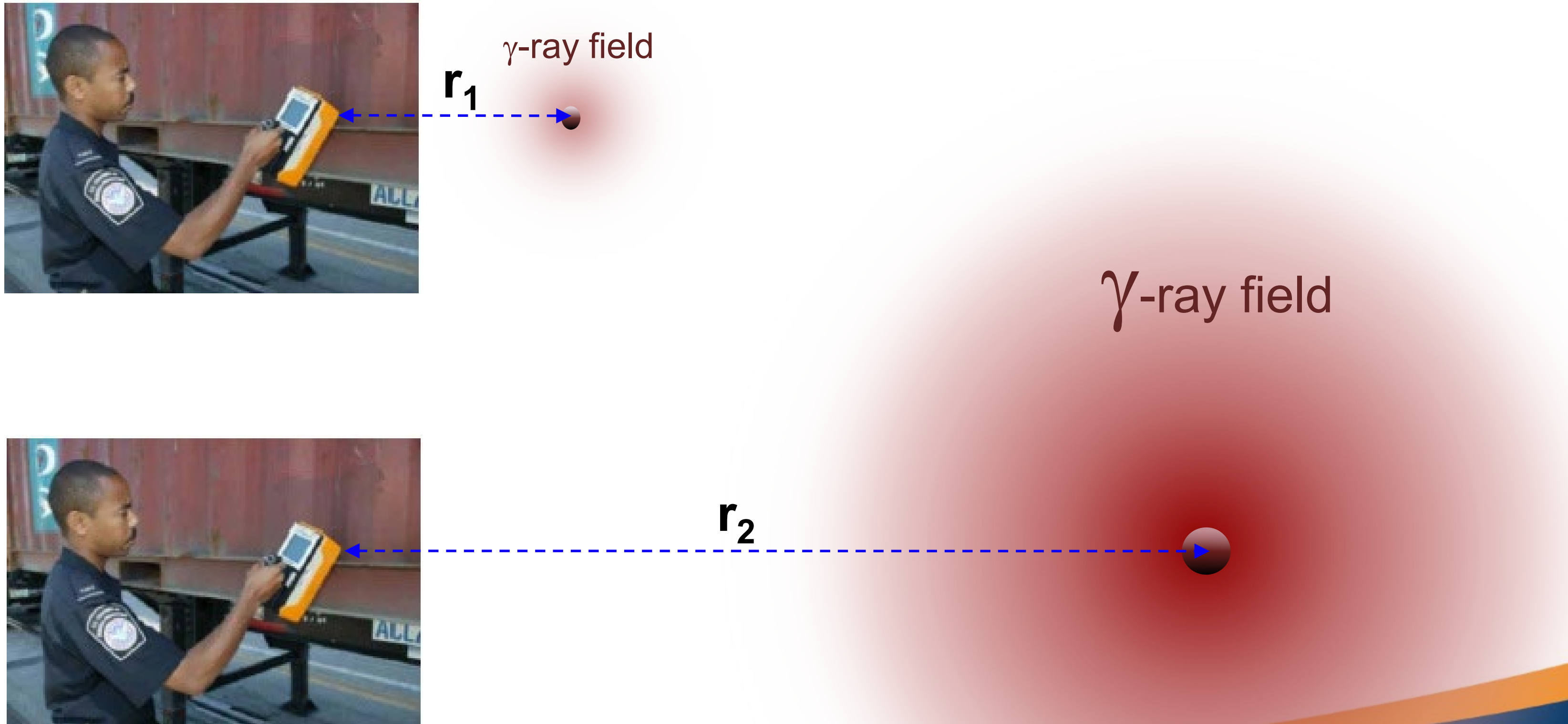
Scattering Study Summary

- Placing the detector on the ground *may* affect the analysis of the data in terms of scattering, but this effect is generally tolerable at the Triage level because Triage is more interested in determining radionuclide ID than quantifying activity/mass precisely.
  - The effect for these measurements was that the estimated activity was ~20 – 30 % lower than actual
  - For these measurements, nuclide identification was minimally affected
- However, if the detector is not aligned with the hotspot other issues may complicate the analysis

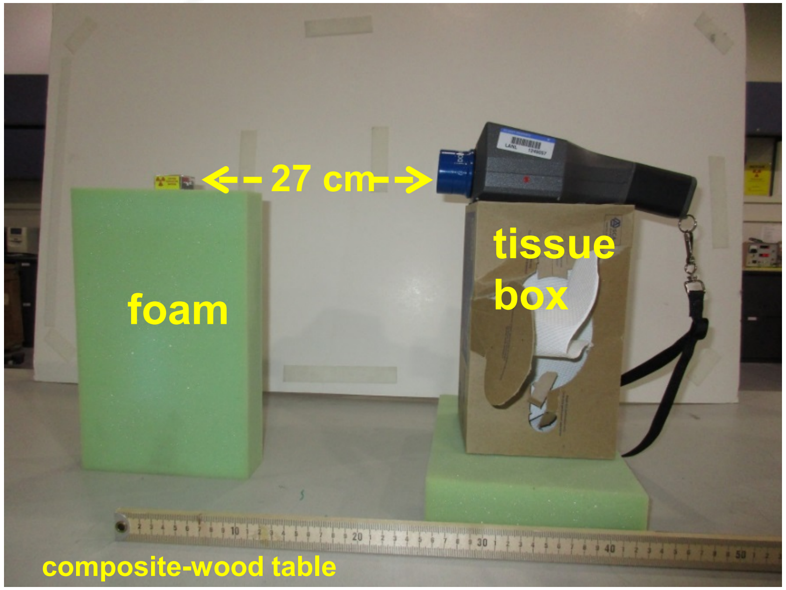
Why do we care about distance?

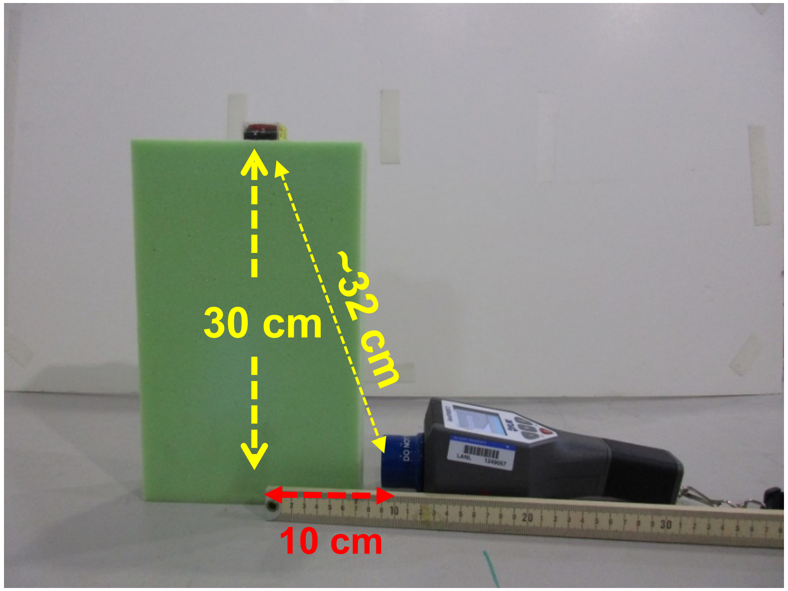
The observed count rate in these two cases *could* be the same.

We need to know the source-to-detector distance to calculate the activity or mass of the source.



Quoting the Wrong Distance



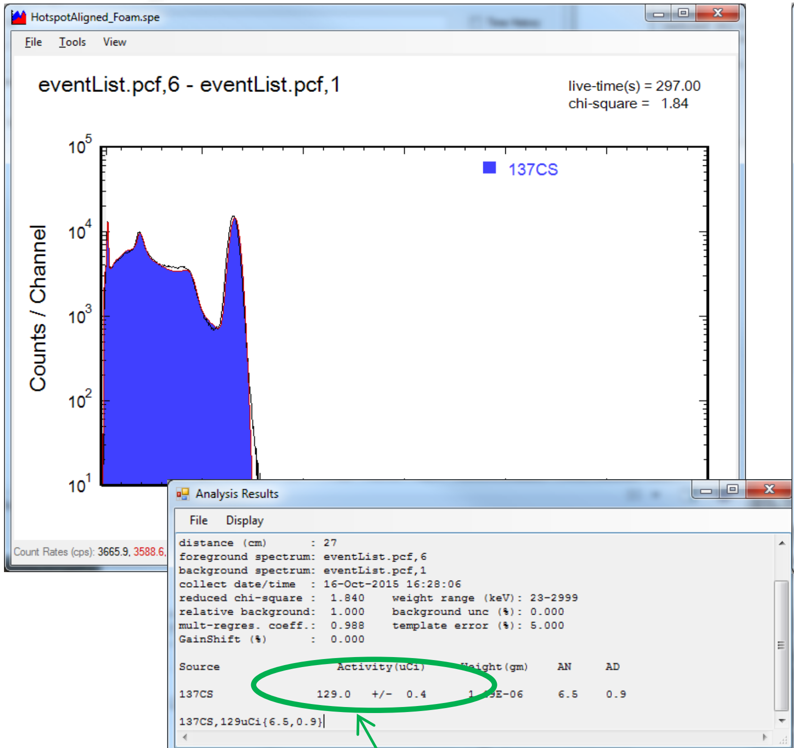


This may seem obvious but to state it for completeness, misaligning the detector and hotspot can result in an incorrectly-assumed distance between the source and detector.

Note also that, in general, detectors are characterized for analysis assuming that the source is <u>in front</u> of the detector.

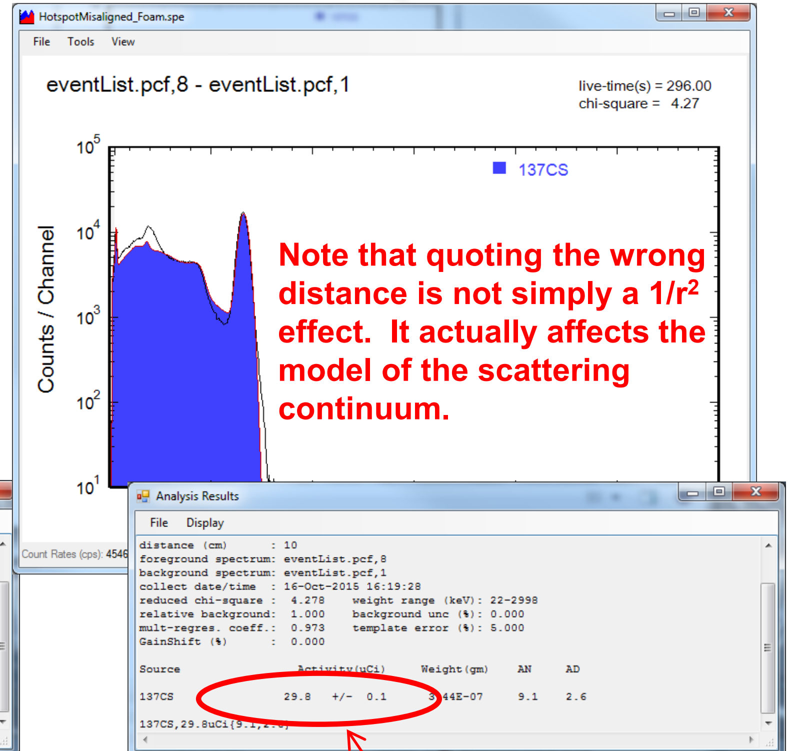
Quoting the Wrong Distance

Using: 27 cm (correct)



With Correct Distance: 129 uCi (low by ~10%)

Using: 10 cm (wrong)

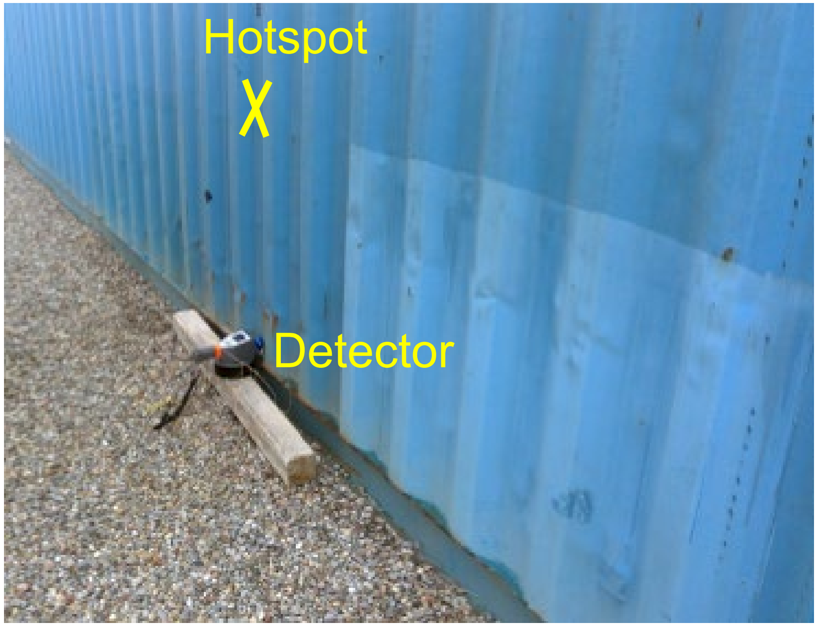


Note that quoting the wrong distance is not simply a $1/r^2$ effect. It actually affects the model of the scattering continuum.

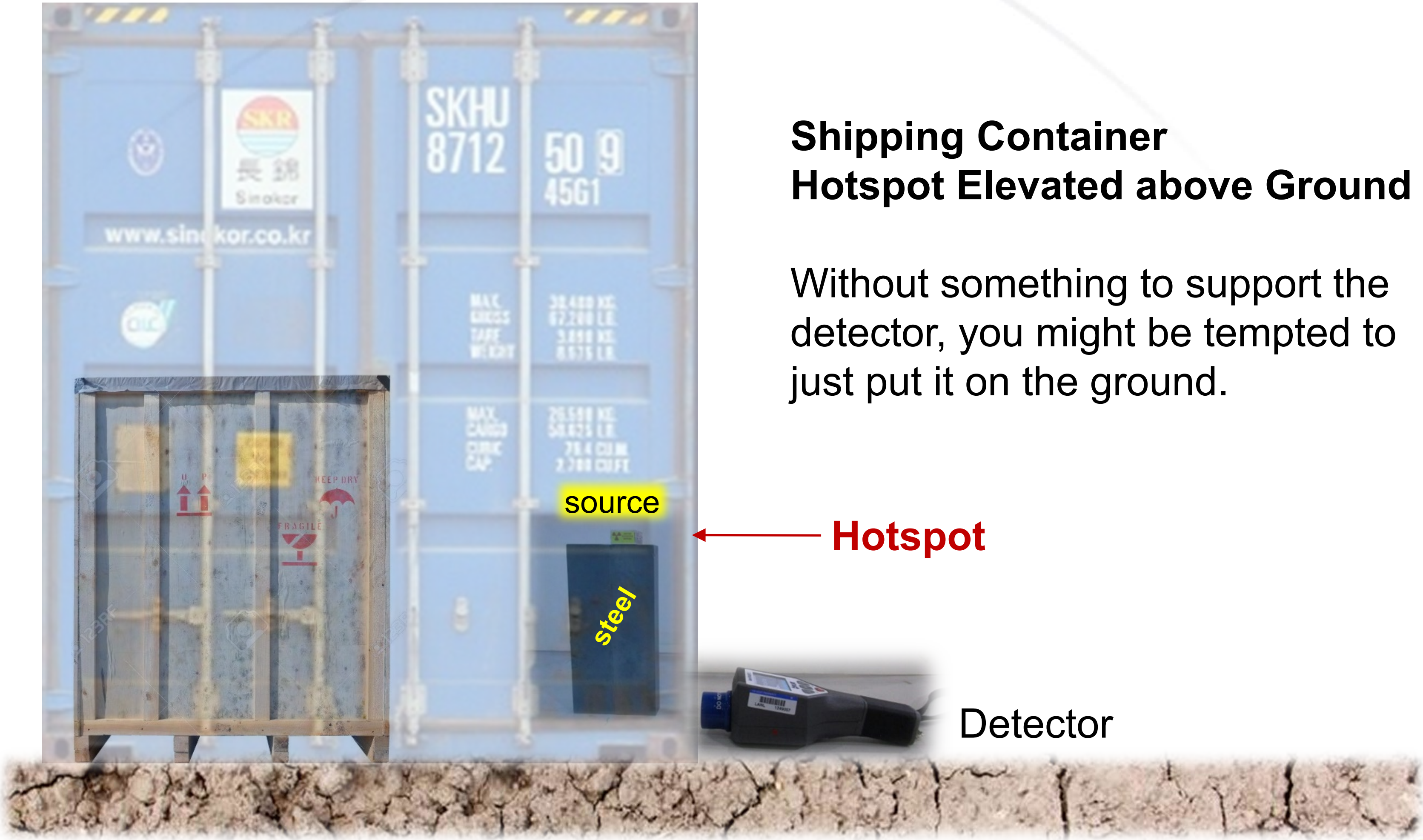
With Incorrect Distance: 30 uCi (low by ~80%)

Distance and Hotspot Alignment

- If the detector taking the spectrum is not aligned with the hotspot
  - A mistake might be made in quoting the source-to-detector distance
  - Intervening materials may obscure the source



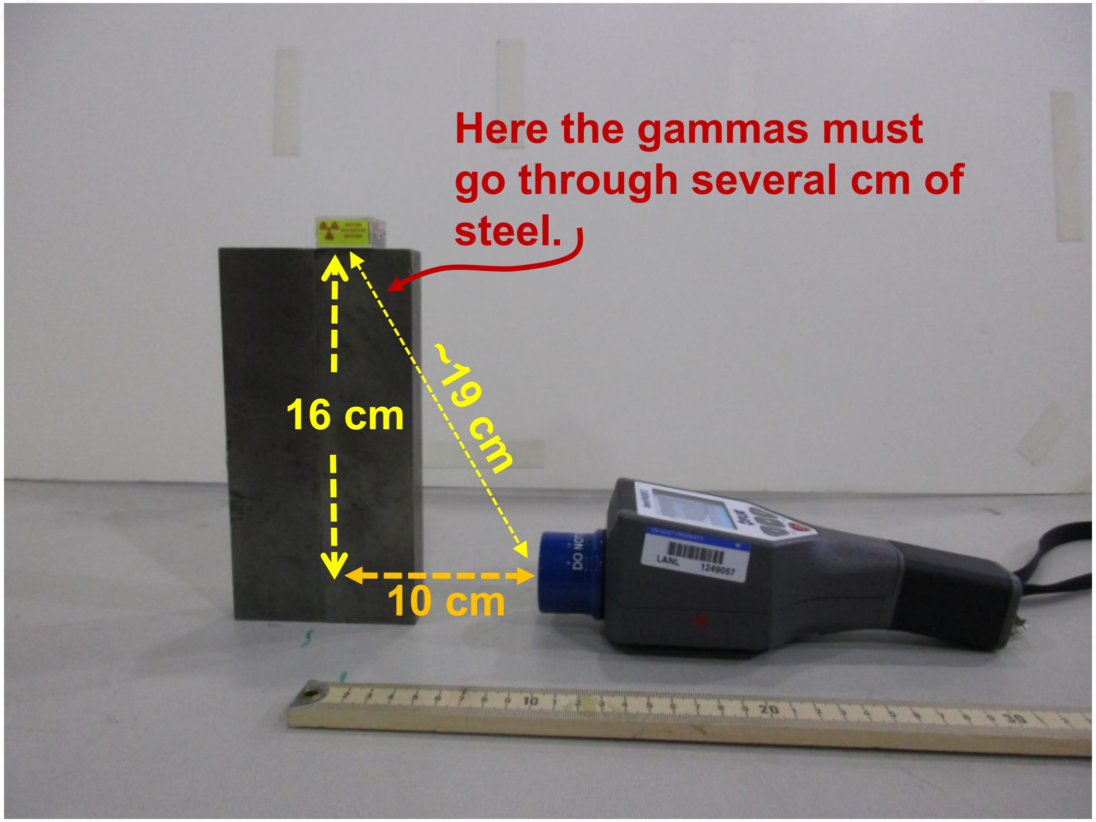
Misalignment with the Hotspot



Shipping Container
Hotspot Elevated above Ground

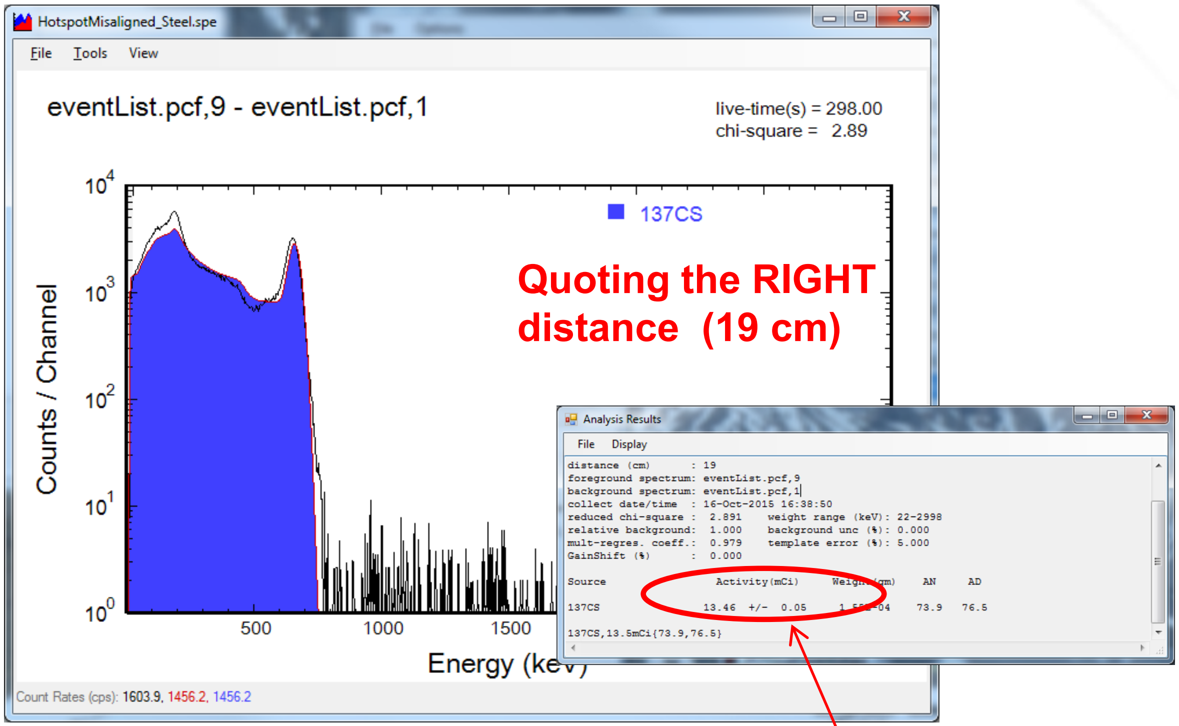
Without something to support the detector, you might be tempted to just put it on the ground.

Misalignment with the Hotspot



We assume that the presence of the steel block on which the source sits is hidden by a container wall. We now may have the wrong distance and unnecessary shielding.

Unnecessary Intervening Materials



The several cm of steel complicates the activity modeling analysis.

Activity calculated as 13.5 mCi (high by a factor of 100)

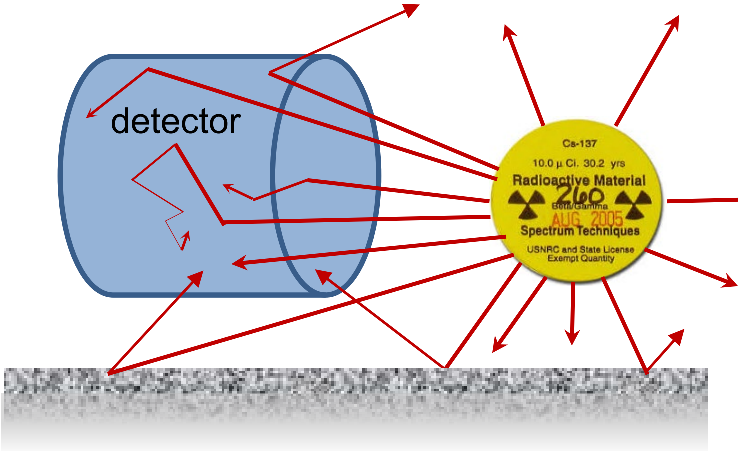
Misalignment Summary

- Misaligning the detector and hotspot *may* skew the analysis results.
- The bottom line is, do the best you can to align the detector with the hotspot.
  - If you can't, then document the measurement configuration as best as possible (photos with fiducials, drawings with dimensions, written descriptions, etc.)

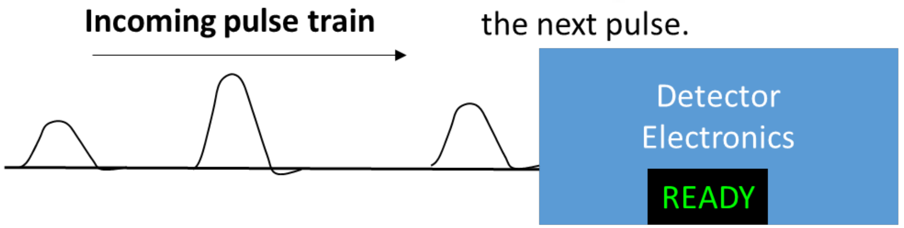
Electronic Dead Time

Detector electronics are busy or “dead” while processing a pulse.

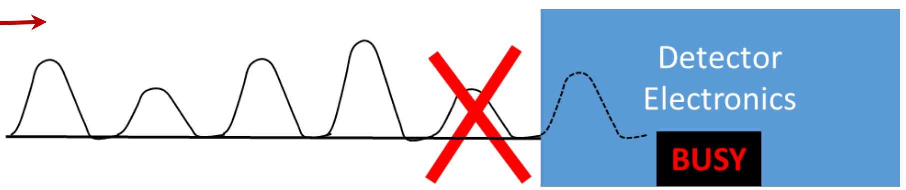
Multiple gammas may hit the detector so close in time that the system can’t process them all.



System is ready to process the next pulse.



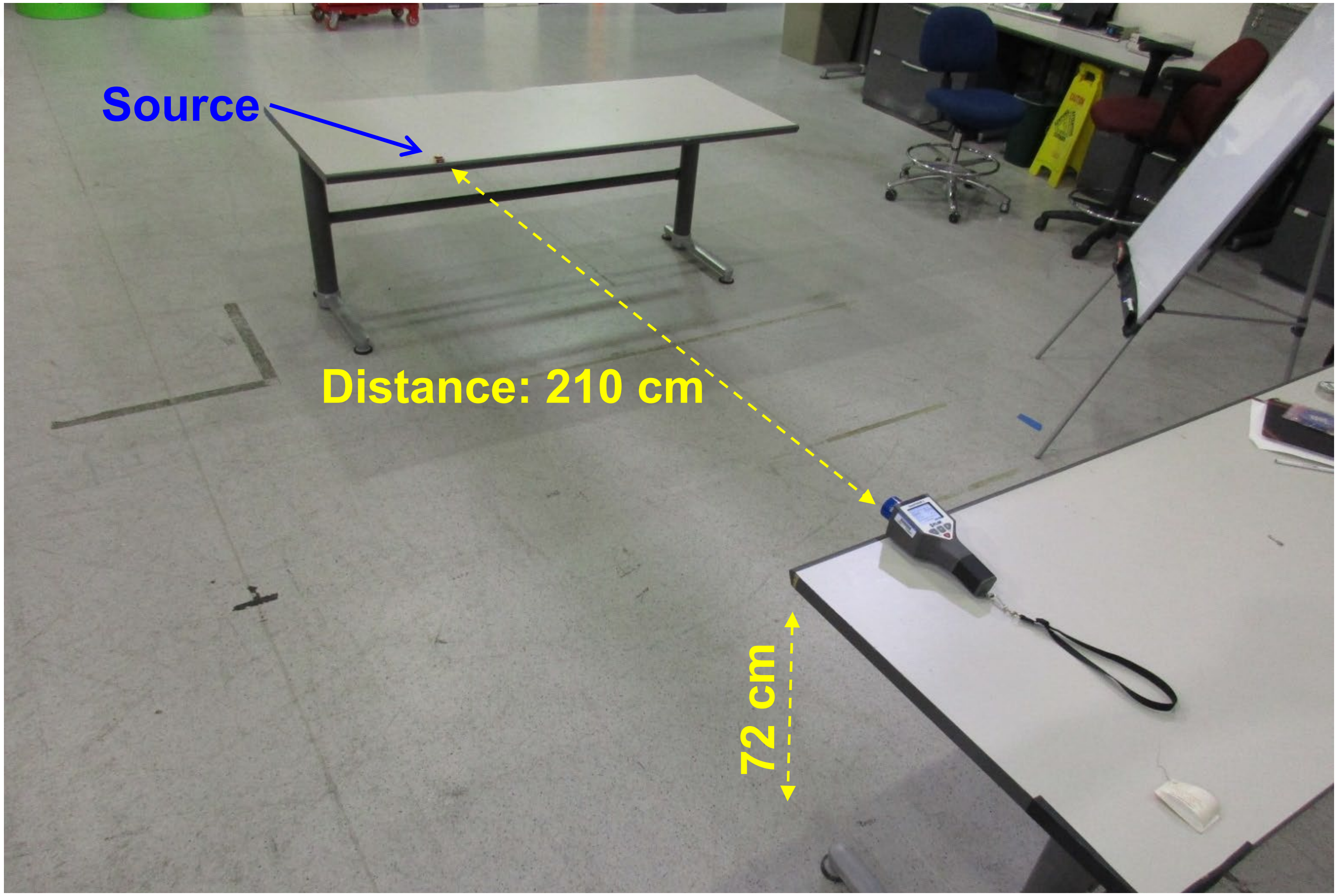
The system is busy processing a pulse so the next pulse is lost.



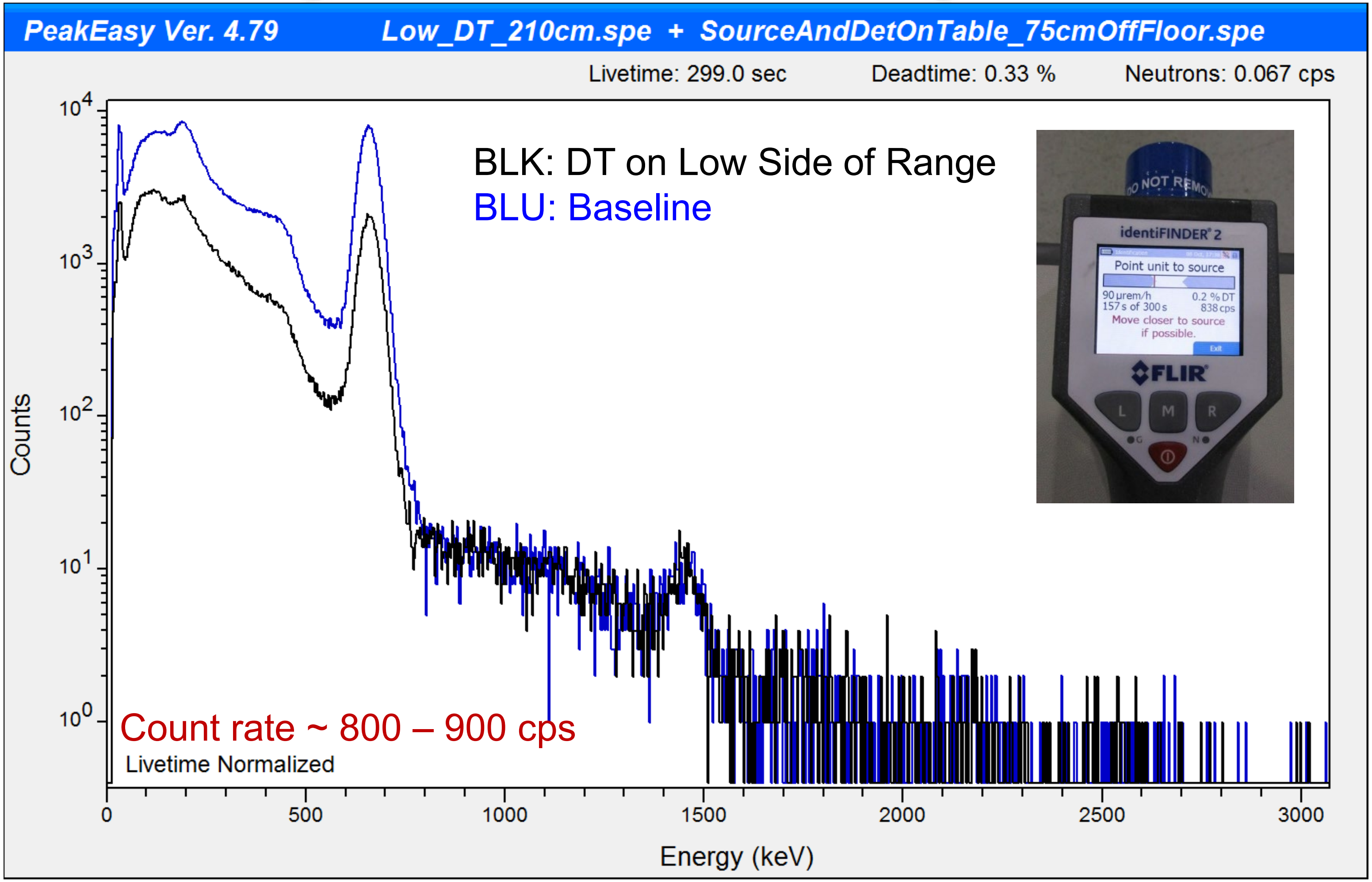
Managing Dead Time

- We can live with the detector being outside the carets.
- If the needle is too high, move away, do not add shielding if possible

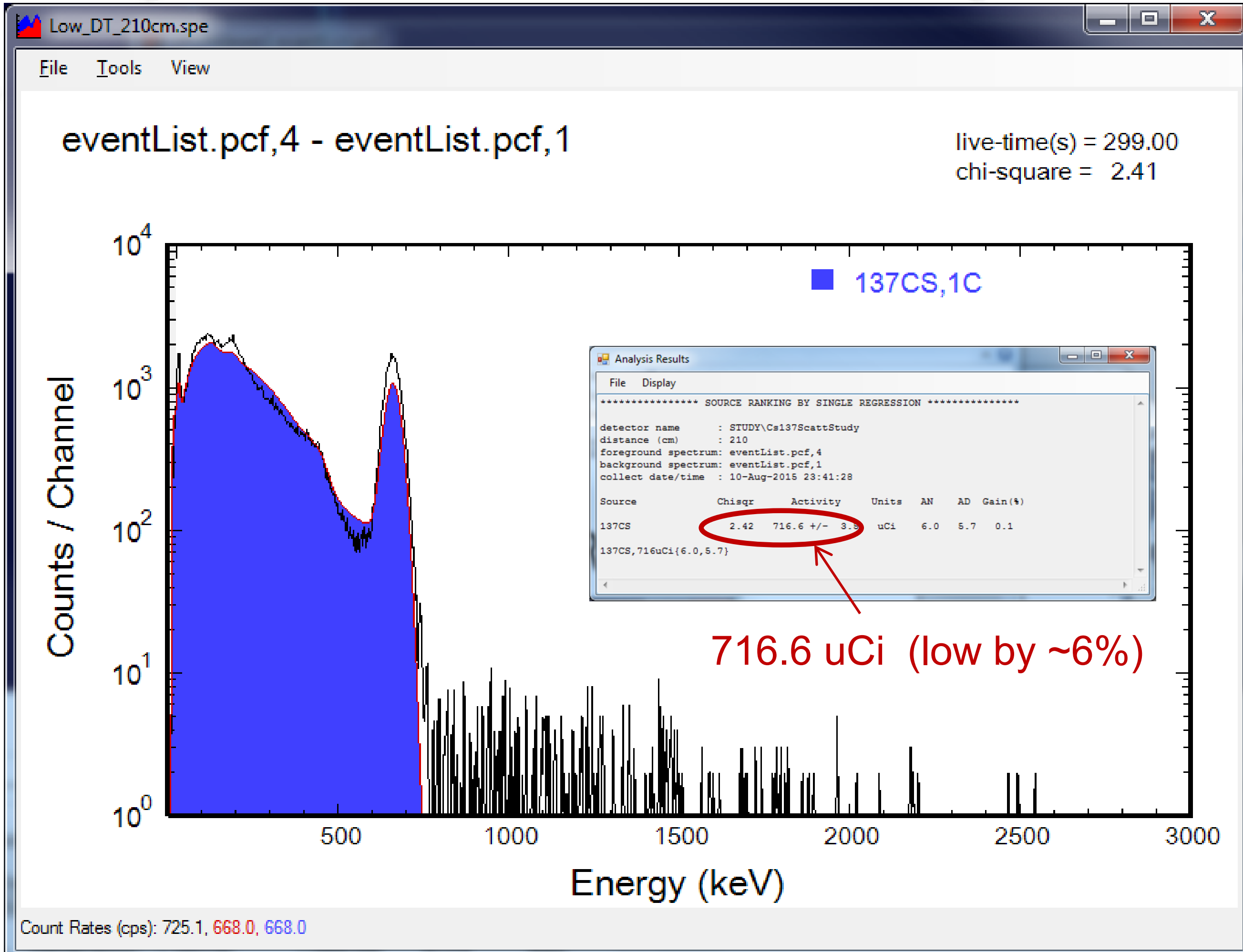
DT on Low Side of Range



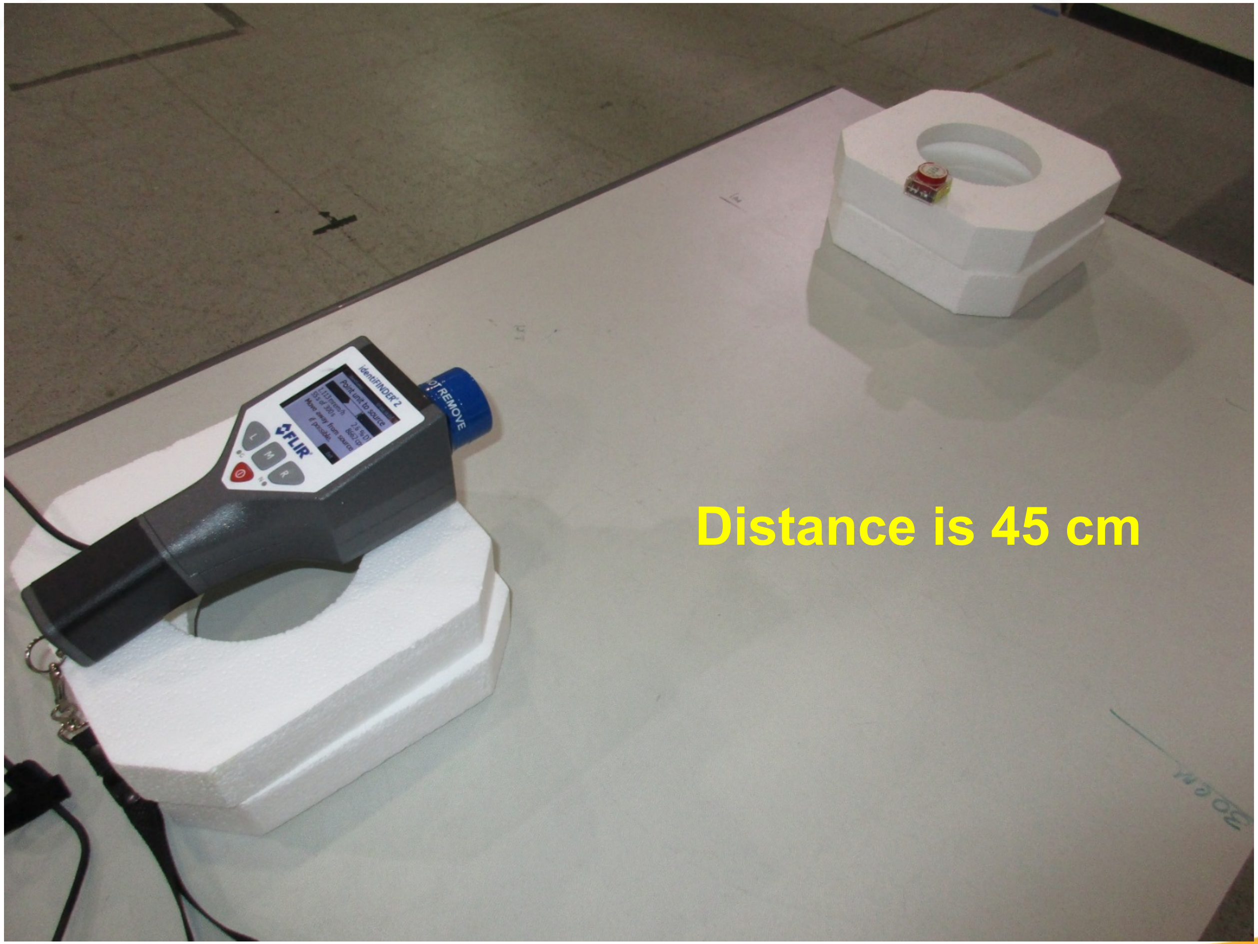
DT on Low Side of Range



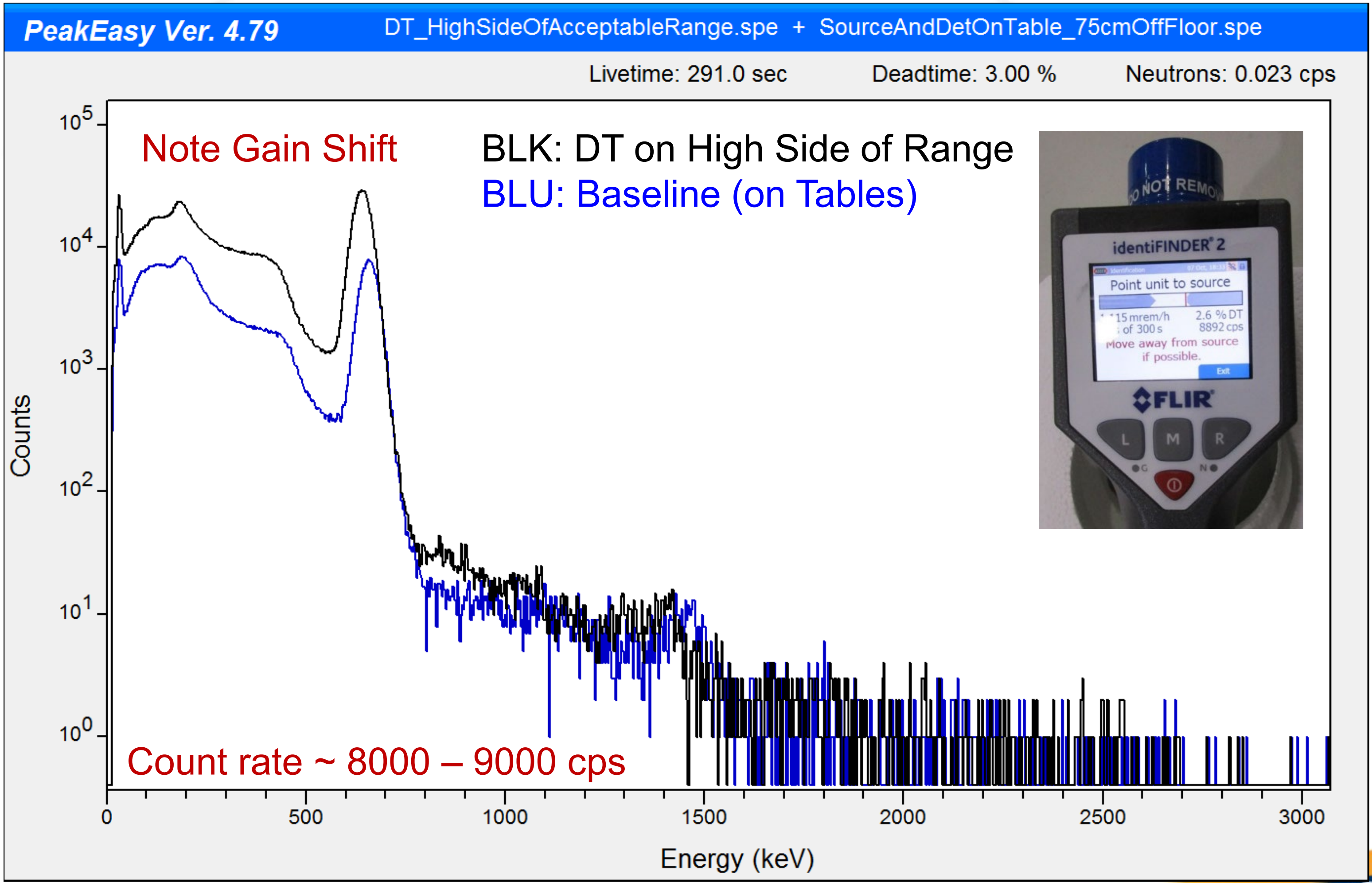
DT on Low Side of Range



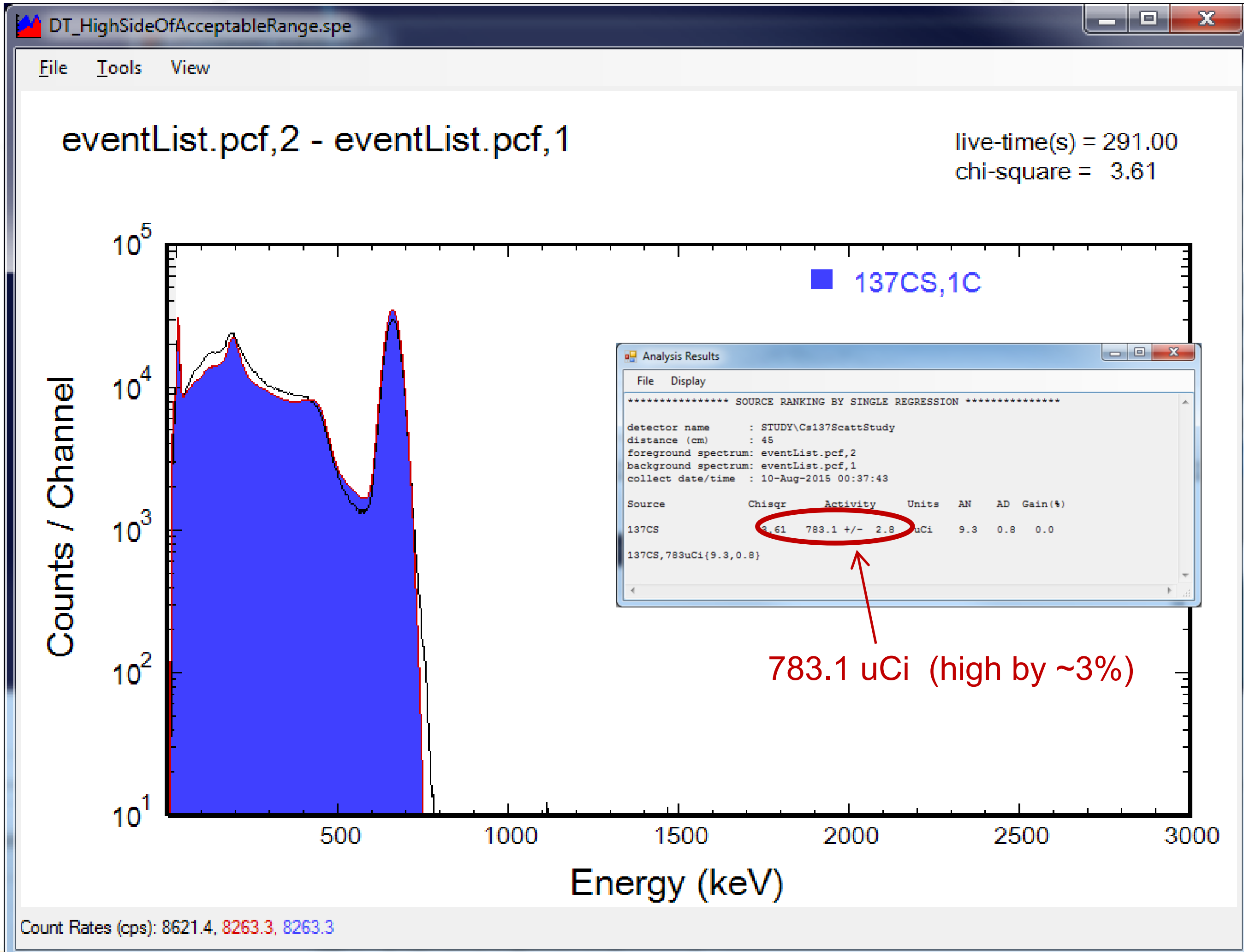
DT on High Side of Range



DT on High Side of Range

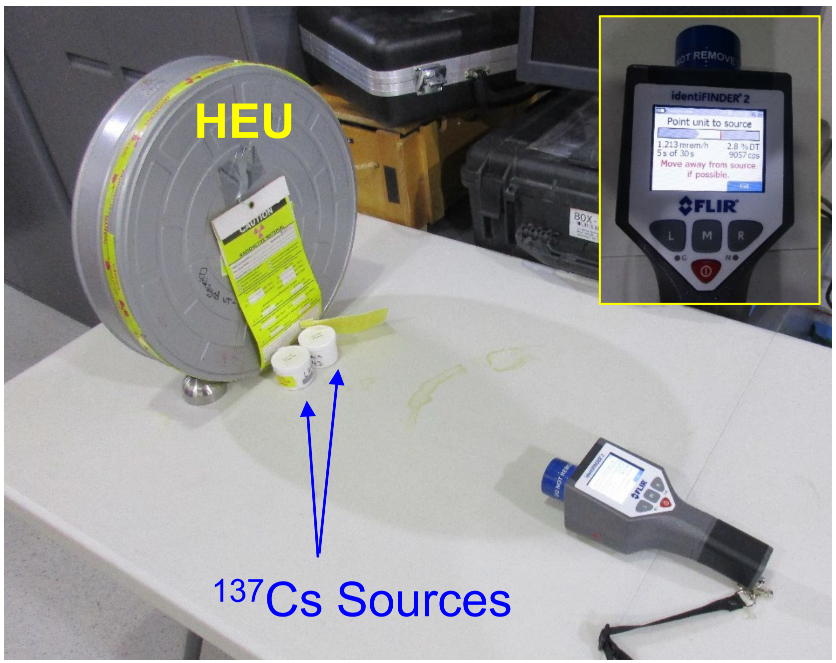


DT on High Side of Range



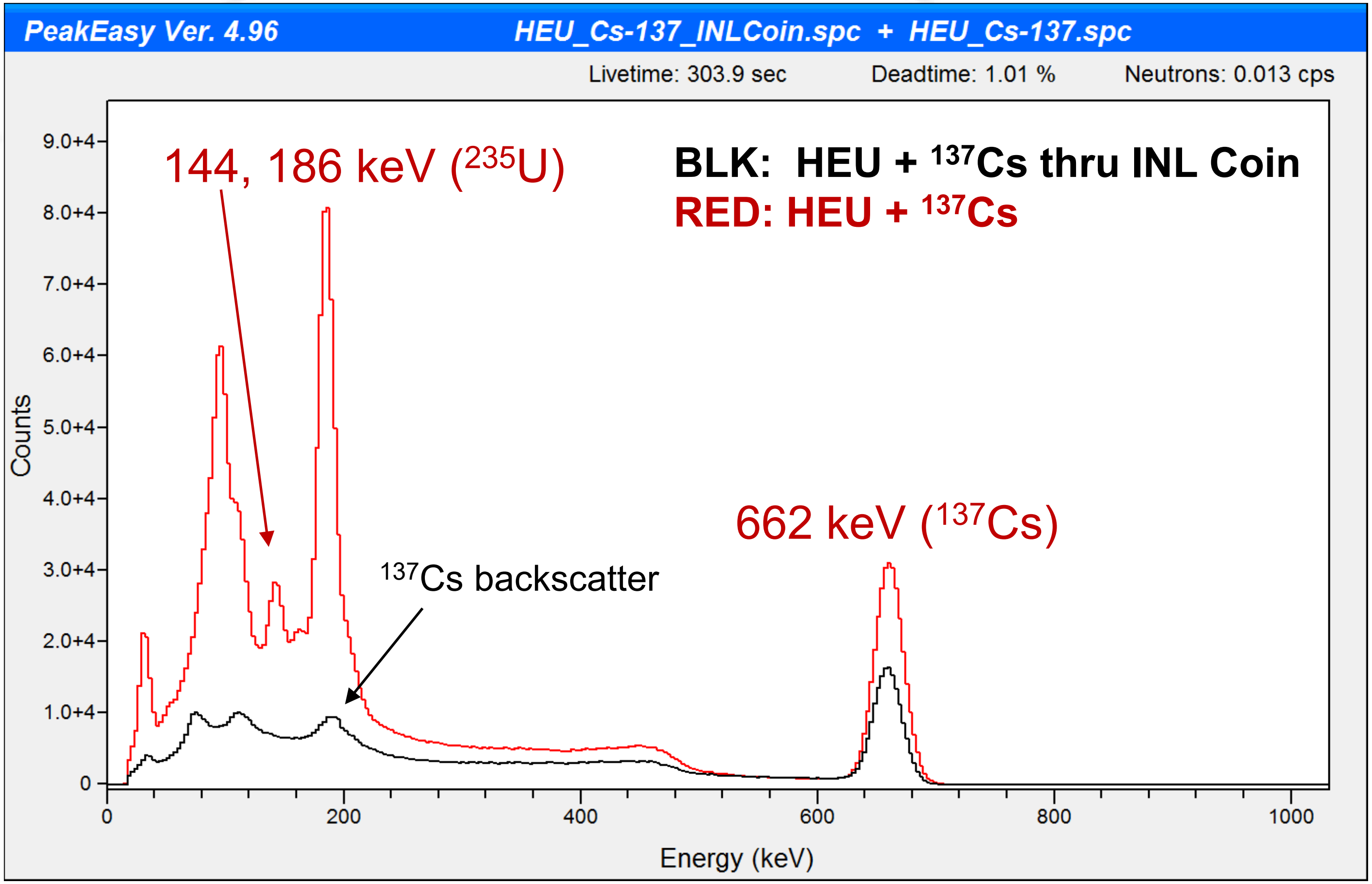
The Danger of Adding Shielding

HEU in Film Can plus two ^{137}Cs sources were measured with and without the INL coin



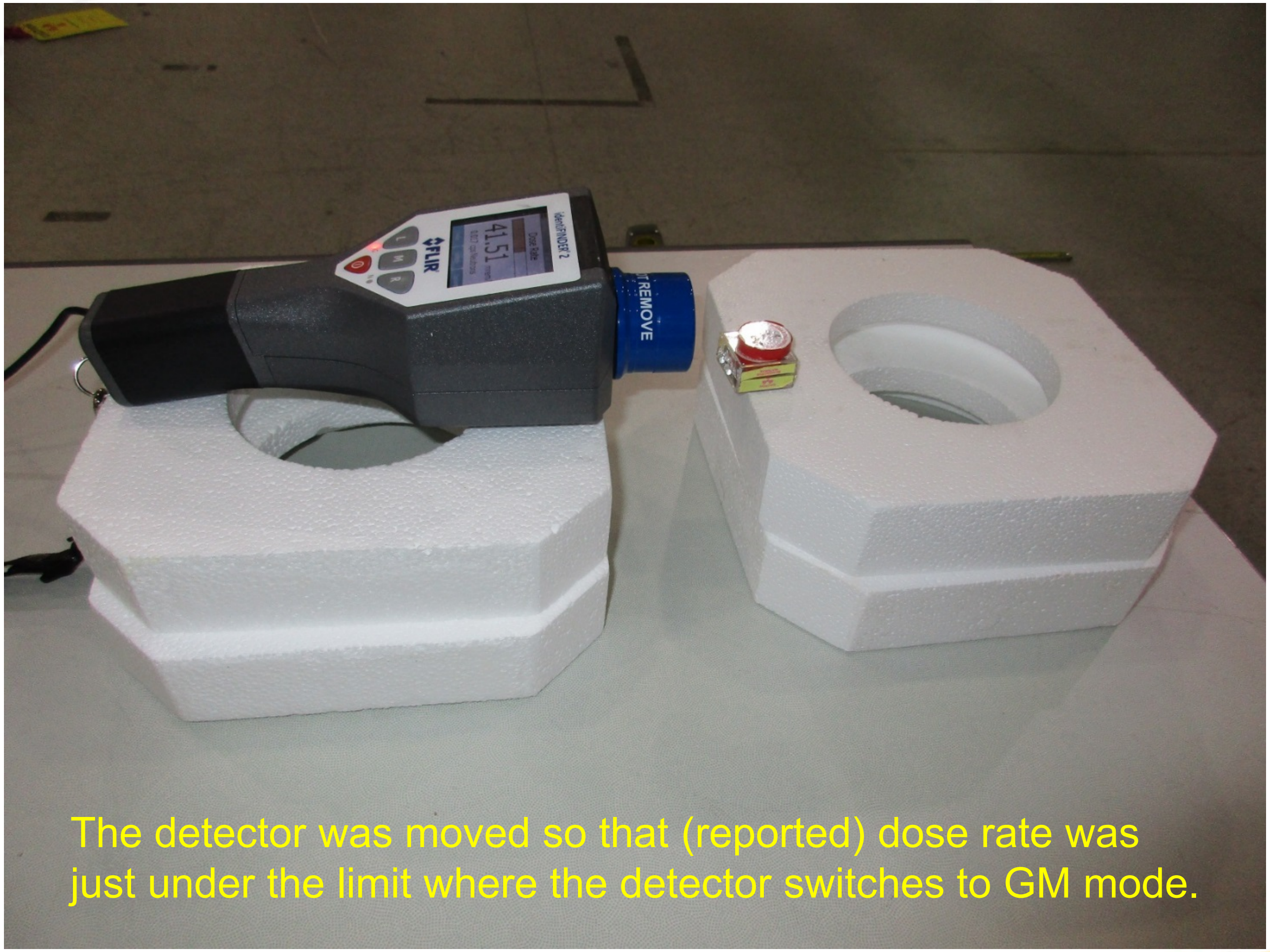
You may be tempted to use shielding to put the IdentiFINDER 'in the carets' – don't.

HEU & ^{137}Cs, Linear Scale

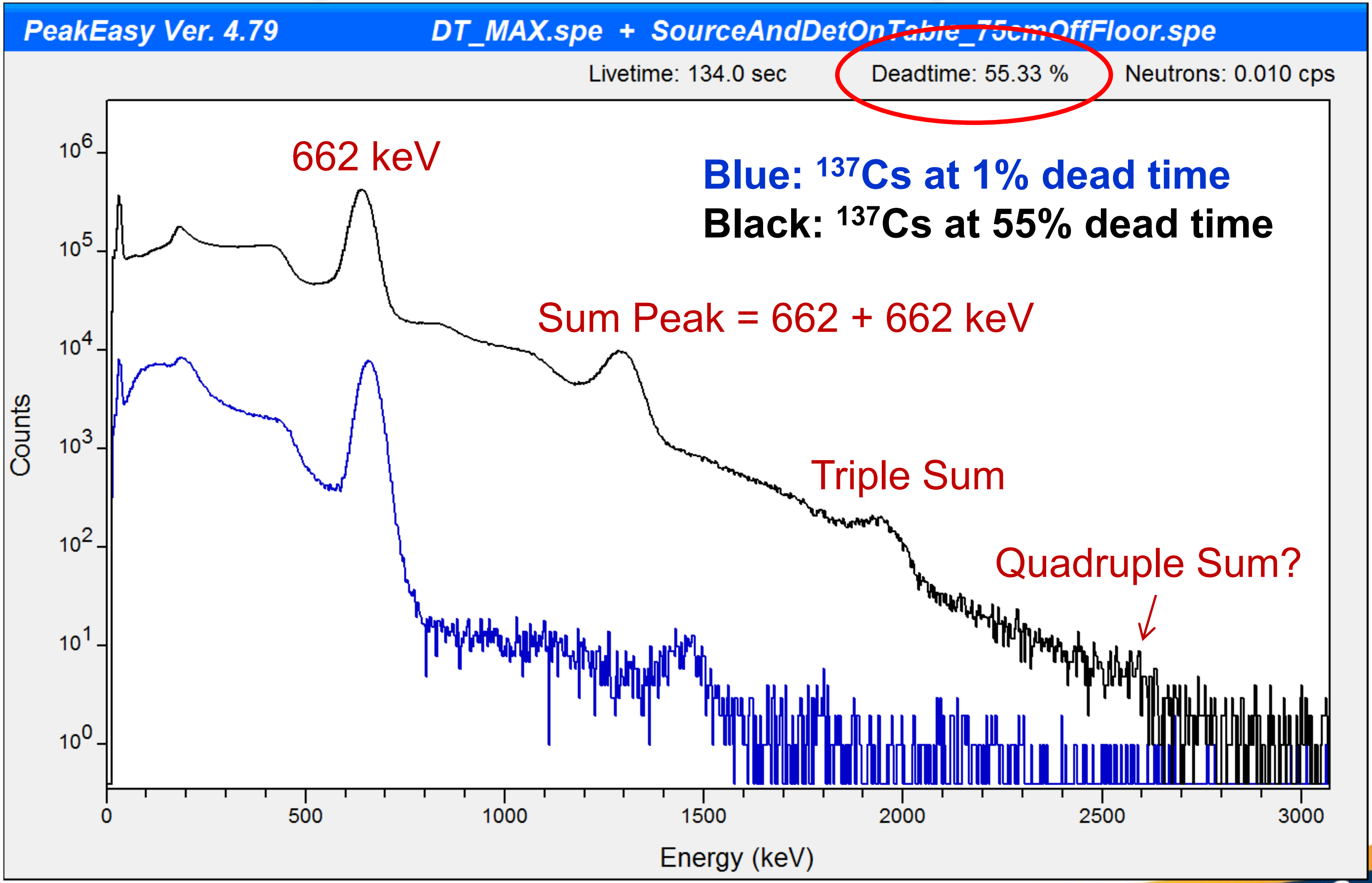


Note that the ¼" of Pb in the INL Coin effectively kills the ^{235}U signature!

Max Dead Time Measurement

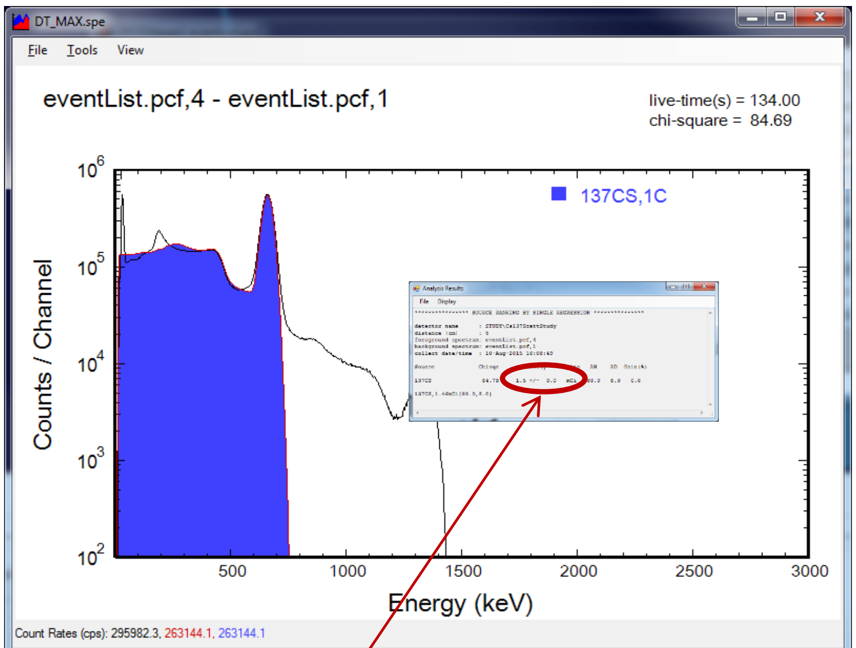


Effects of High Dead Time



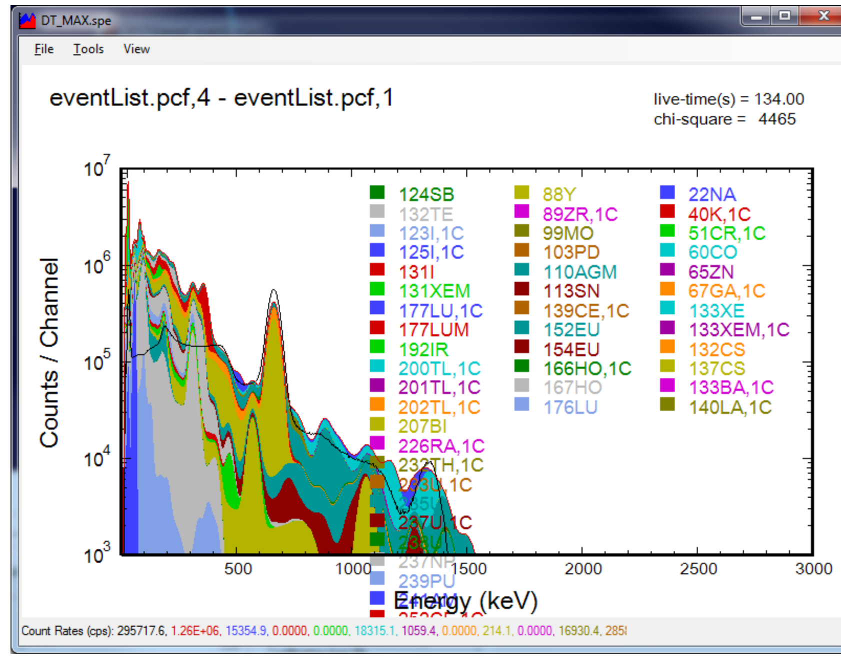
Max DT Spectrum Analysis

Assuming you know it's ^{137}Cs:



1500 uCi (high by ~100%)

'automatic nuclide identification':



Max Tolerable Dose Rate(s)?

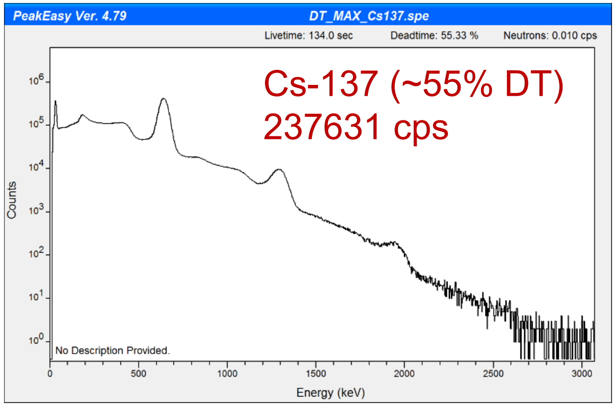
4 different sources were used to push the IdentiFINDER2 reported dose rate until the 'GM-mode' was entered.

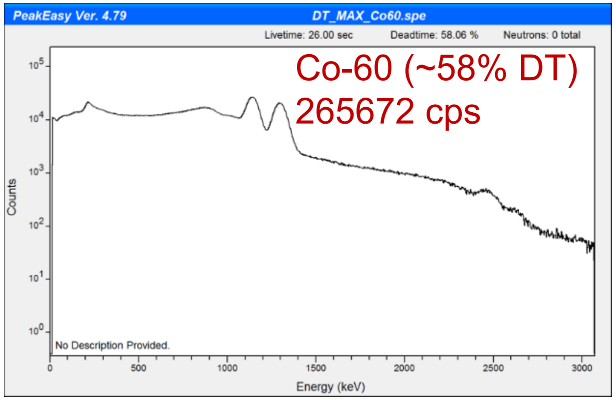
Reported Dose Rates [mrem/hr]			
Source	**Ident (NaI)**	**Ident (GM)**	**RadEye**
Cs-137	42	8	4
Ba-133	15	5	1.5
Co-60	23	15	2
Am-241	5	0	0.8

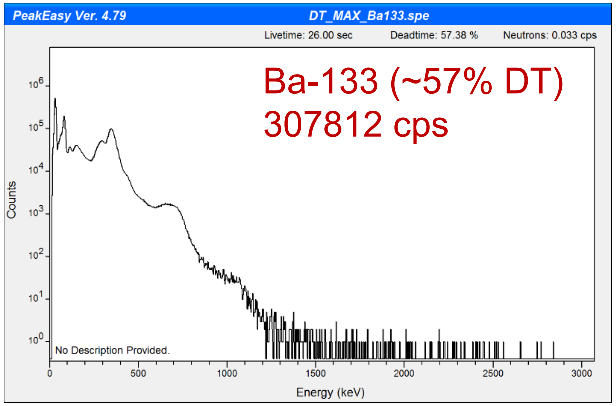
For these measurements the RadEye was placed as close as possible to the position of the IdentiFINDER NaI crystal relative to each source.

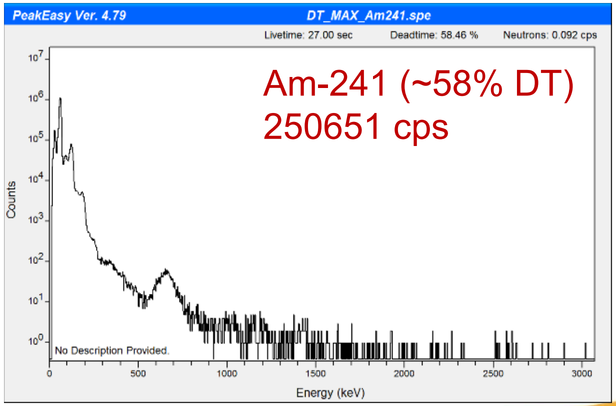
Max Tolerable DT Spectra

Even though the reported dose rates were different for these sources at the turn-over to GM mode, <u>the dead times were effectively the same</u>.









Dead Time Summary

- Dead time within the design range is ~0.3 – 3%
- Data taken at the low end of this range simply suffers from low statistics for a given real time.
- Data taken at the high end of this range causes an apparent gain shift but does not really affect analysis of the data.
- Data taken above this high-DT limit can significantly affect the spectrum.

IdentiFINDER2 & Neutrons

'Spectrum orientation'

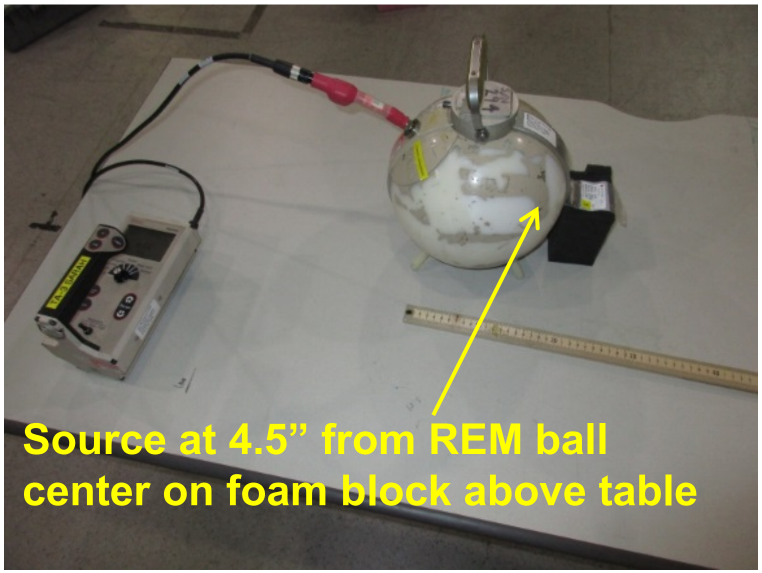
"**Red Dot**", most neutron-efficient orientation

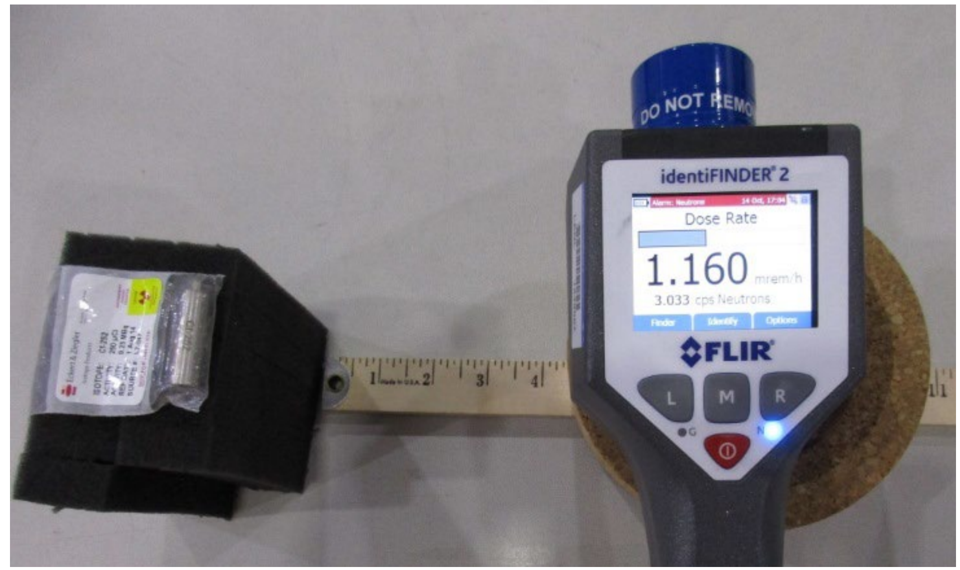
Gamma Dose Rate: **13.0 mrem/h**
Neutron Count Rate: 36 cps

Gamma Dose Rate: 2.7 mrem/h
Neutron Count Rate: **100 cps**

The above illustrates that the quoted dose rate is based on gamma (GM tube or NaI) and not neutron count rate.

Neutron Dose Rate and CPS





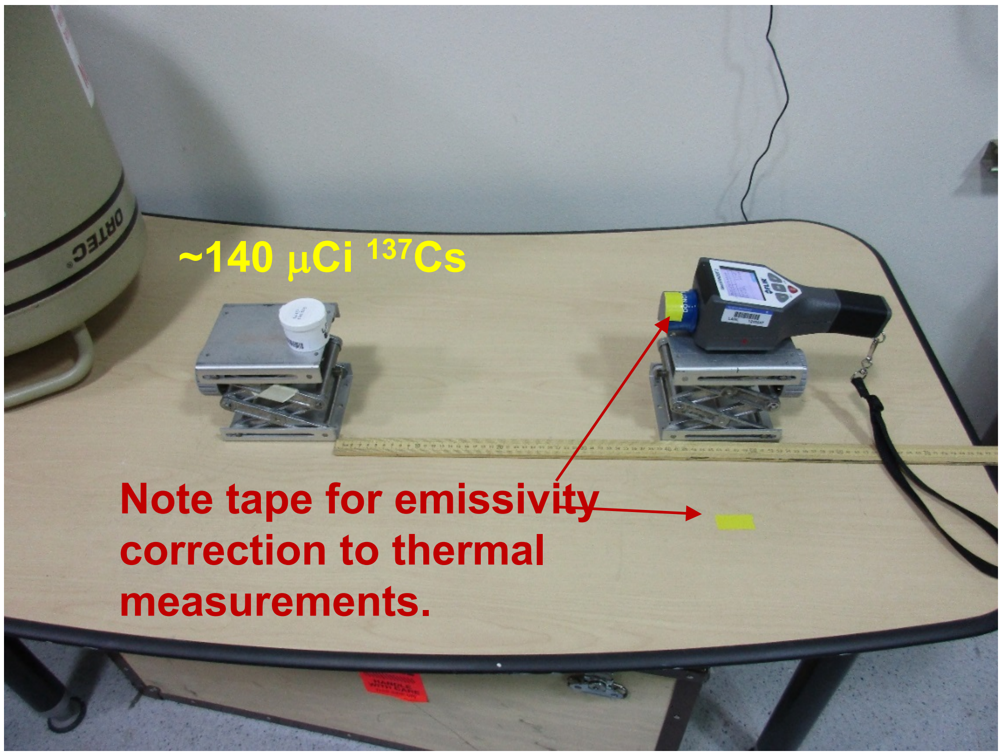
Neutron Dose Rate ~ 70 mR/h at 4.5" **(contact with REM Ball)**

Neutron Count Rate at 4.5" on foam block above table: ~ 3 cps
(but this rate will change with moderation!)

Effects of Temperature

- Goal was to study dependence of NaI RIID performance on temperature.
- NaI IdentiFINDER 2 cooled in refrigerator overnight
- Measured sources in lab in successive 5-minute spectra where temp was ~75 F
- Non-contact temperature readings taken with FLIR i60 thermal imager.
  - Tape was placed on the detector crystal and the table
  - FLIR emissivity parameter was set to 'tape' 0.96

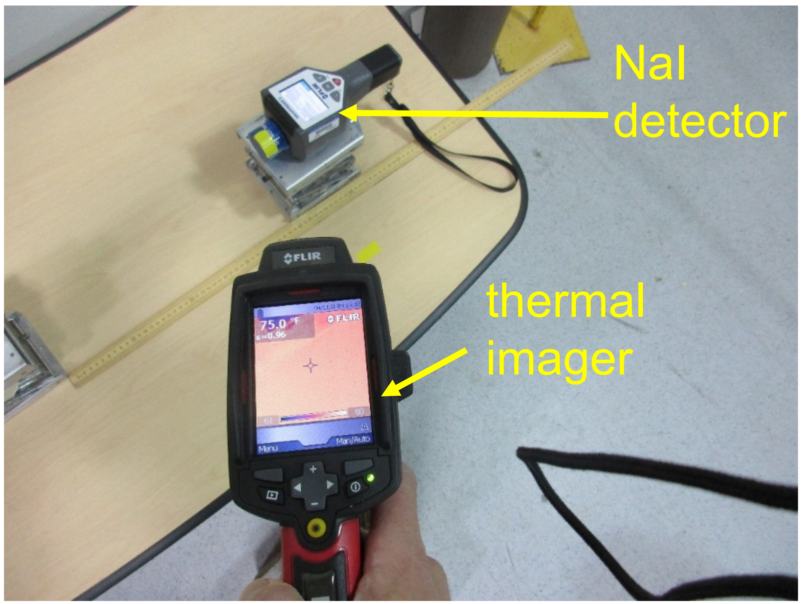
Measurement Setup



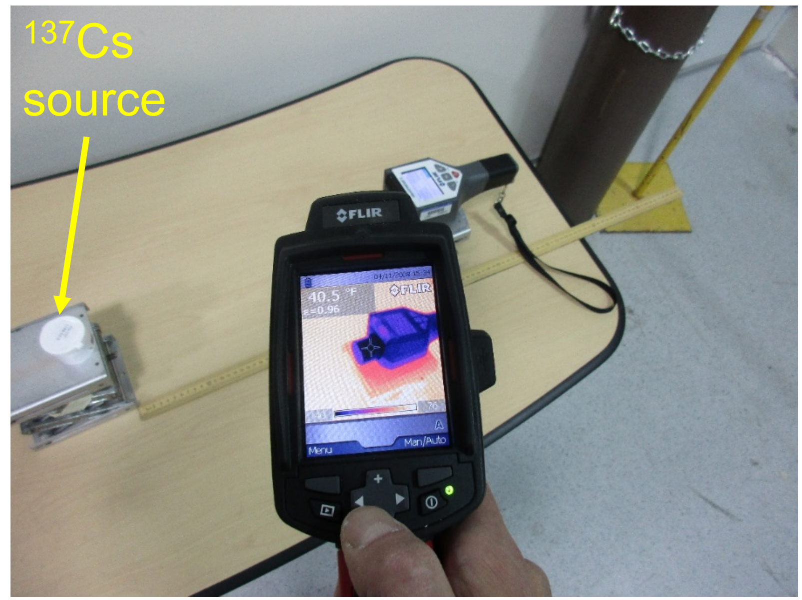
Scintillator Temperature Behavior

A NaI detector was cooled in a refrigerator until it was 40 F and then data were taken with a ^{137}Cs source as it warmed.

Room temp was approximately 75 F at table top.

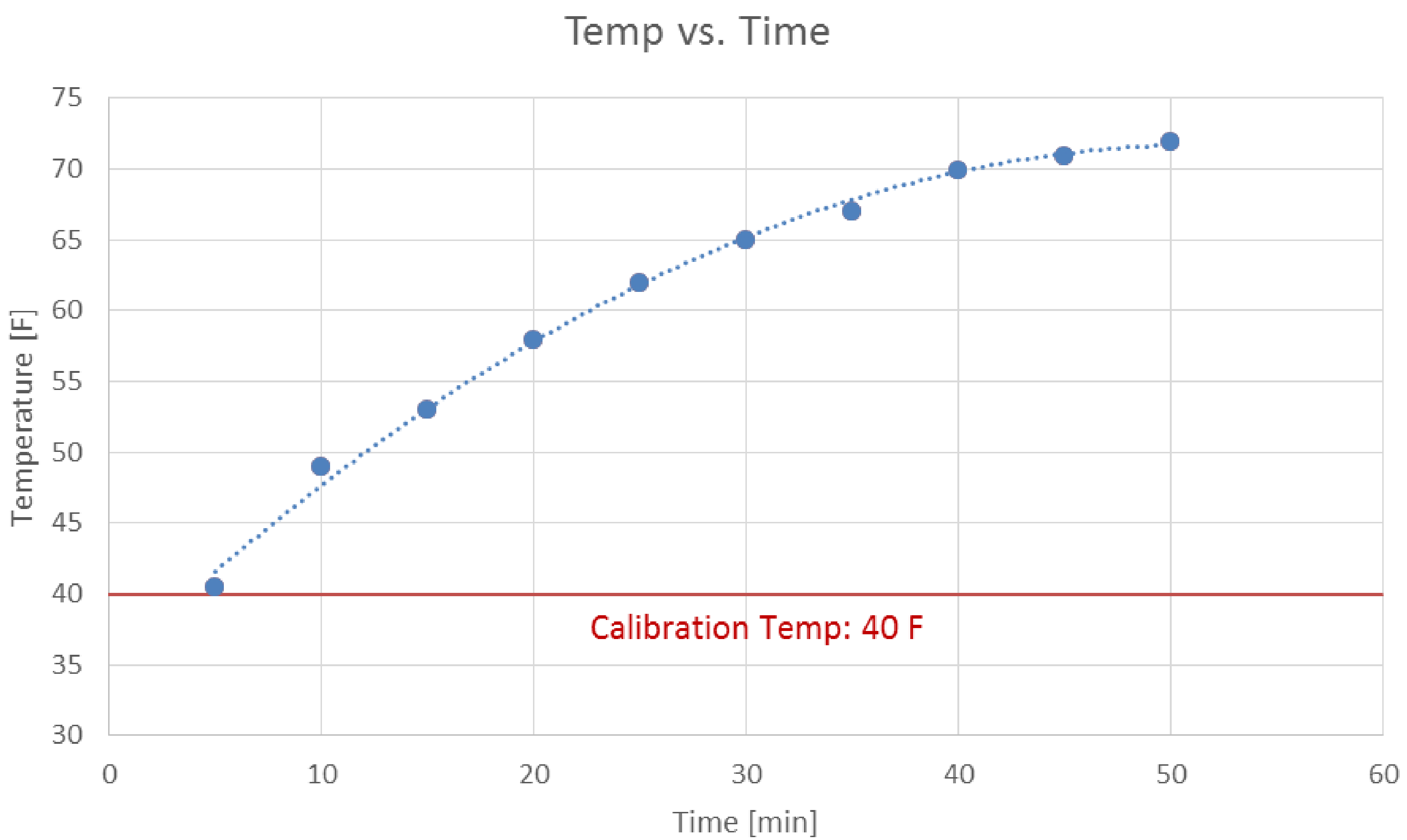


Initial detector temp was ~ 40 F at crystal.



Note: tape was placed on the detector and table top for a controlled emissivity.

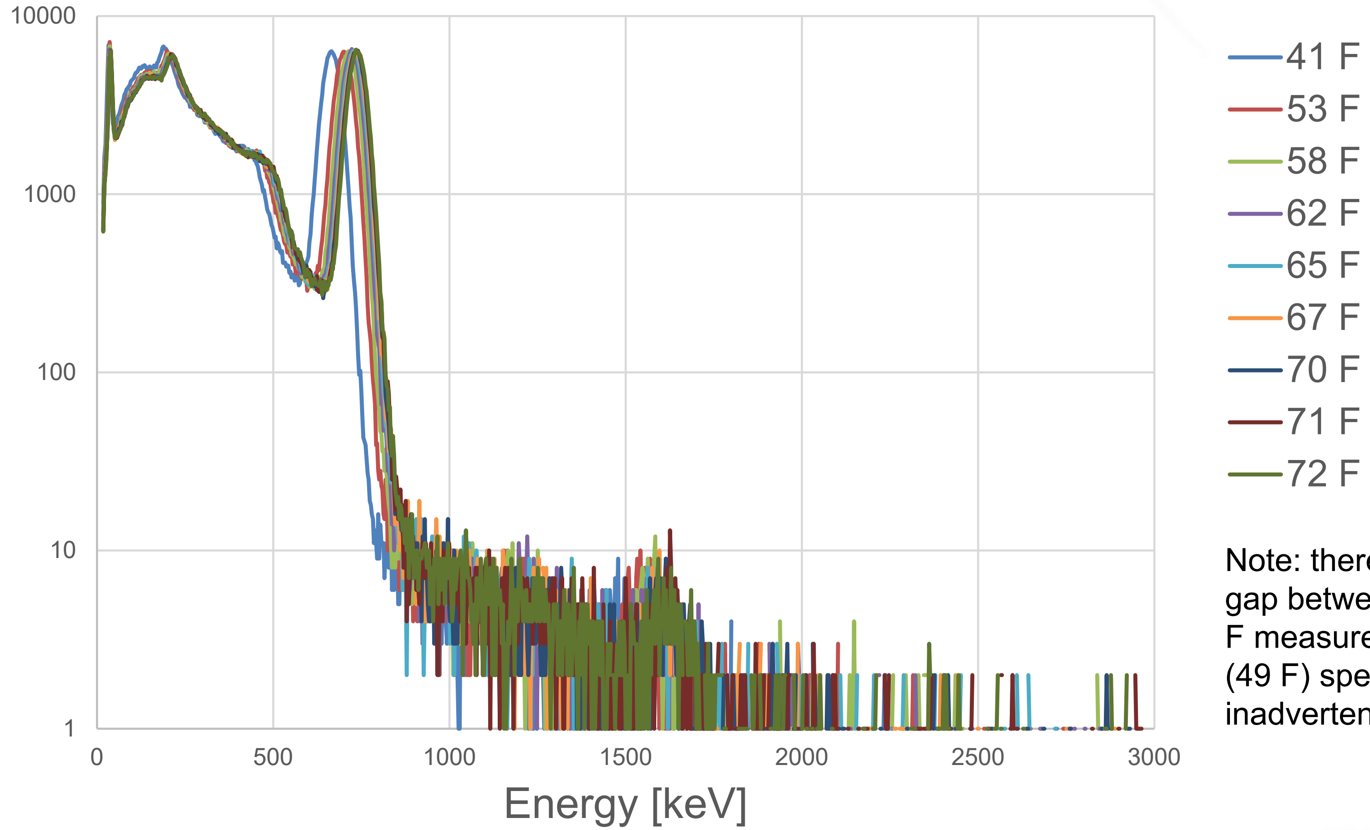
Temperature Readings vs. Time



Final Temperature

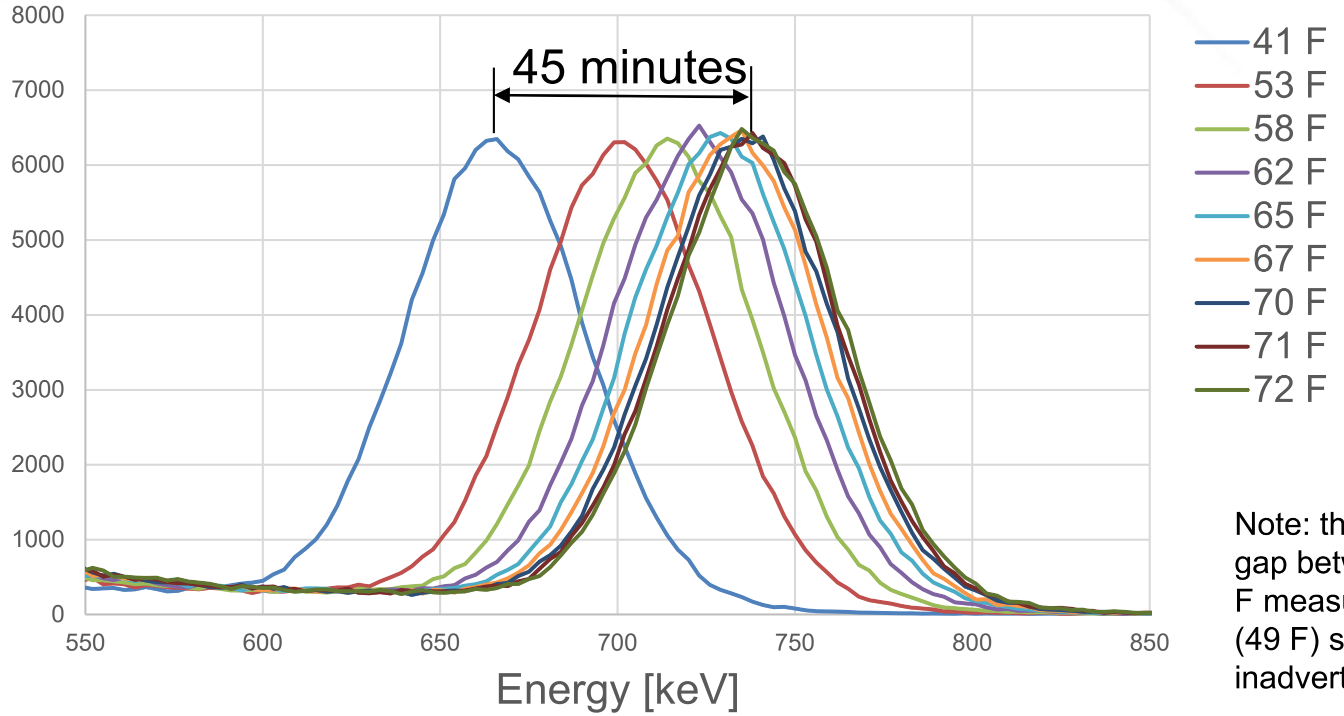
Final temp was approximately 73 F at crystal.

^{137}Cs Spectra vs Temperature



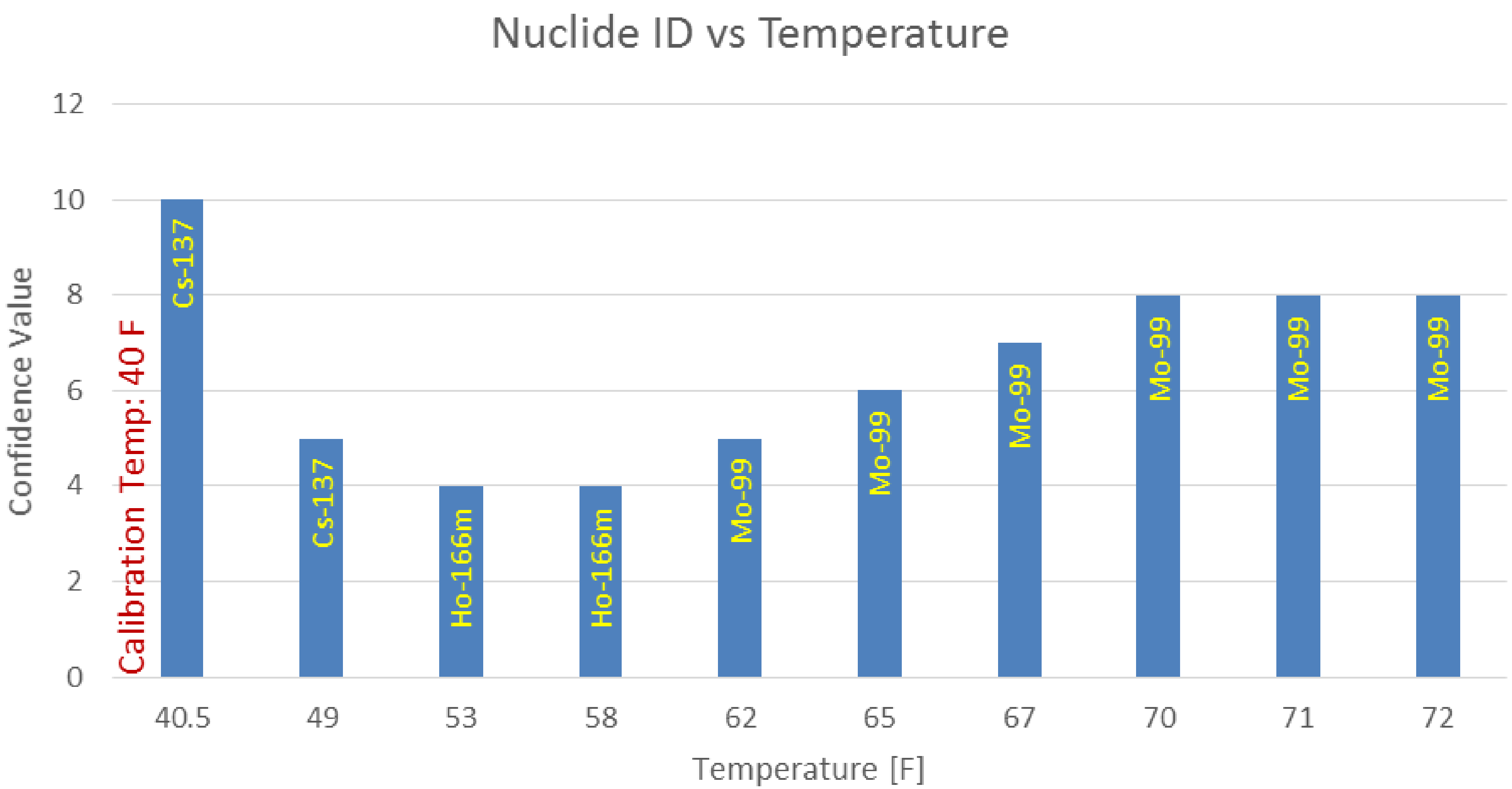
Note: there was a 10-minute gap between the 41 F and 53 F measurements as the 2nd (49 F) spectrum was inadvertently not saved.

^{137}Cs 662-keV Peak versus Temperature

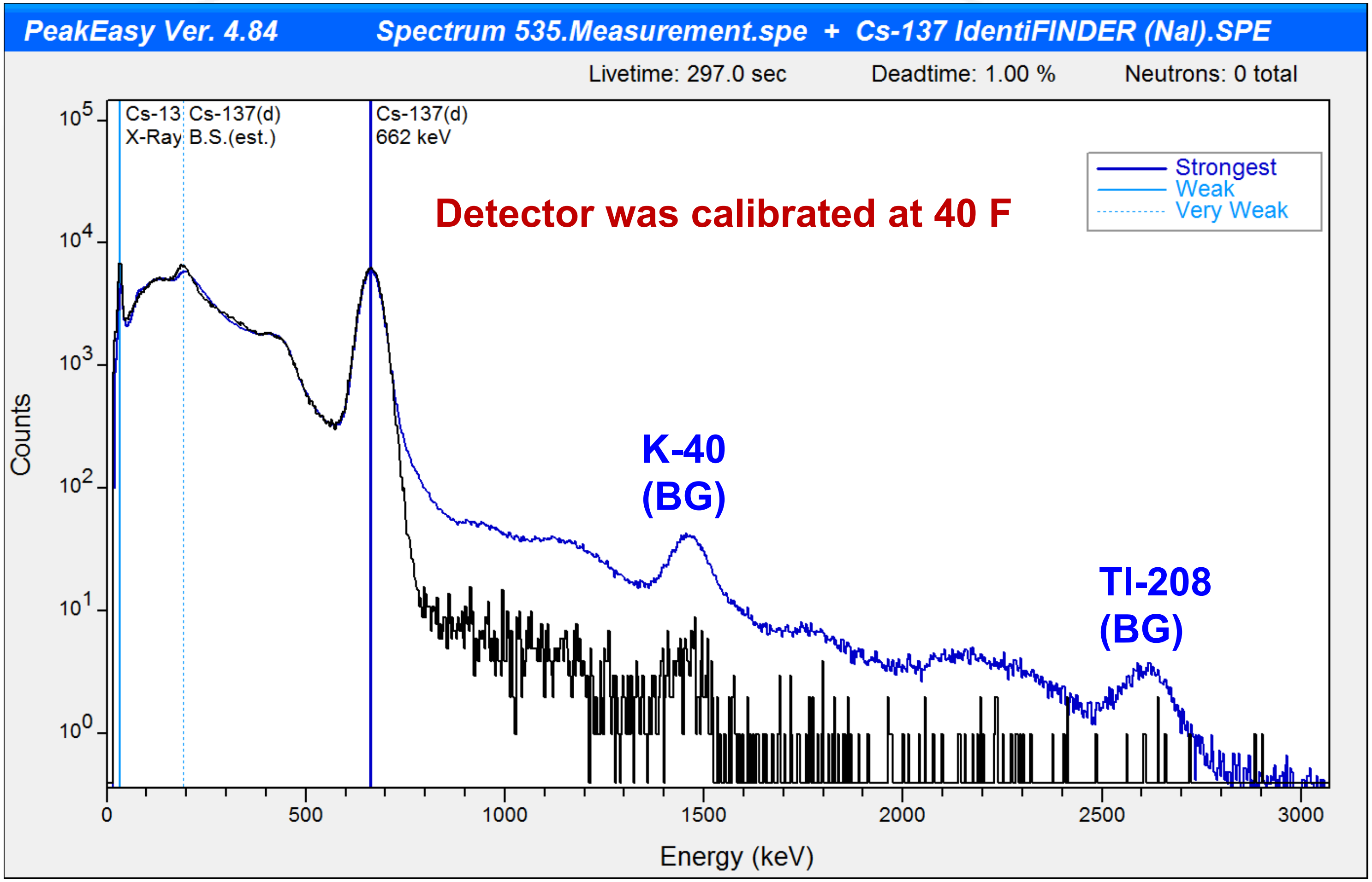


Note: there was a 10-minute gap between the 41 F and 53 F measurements as the 2nd (49 F) spectrum was inadvertently not saved.

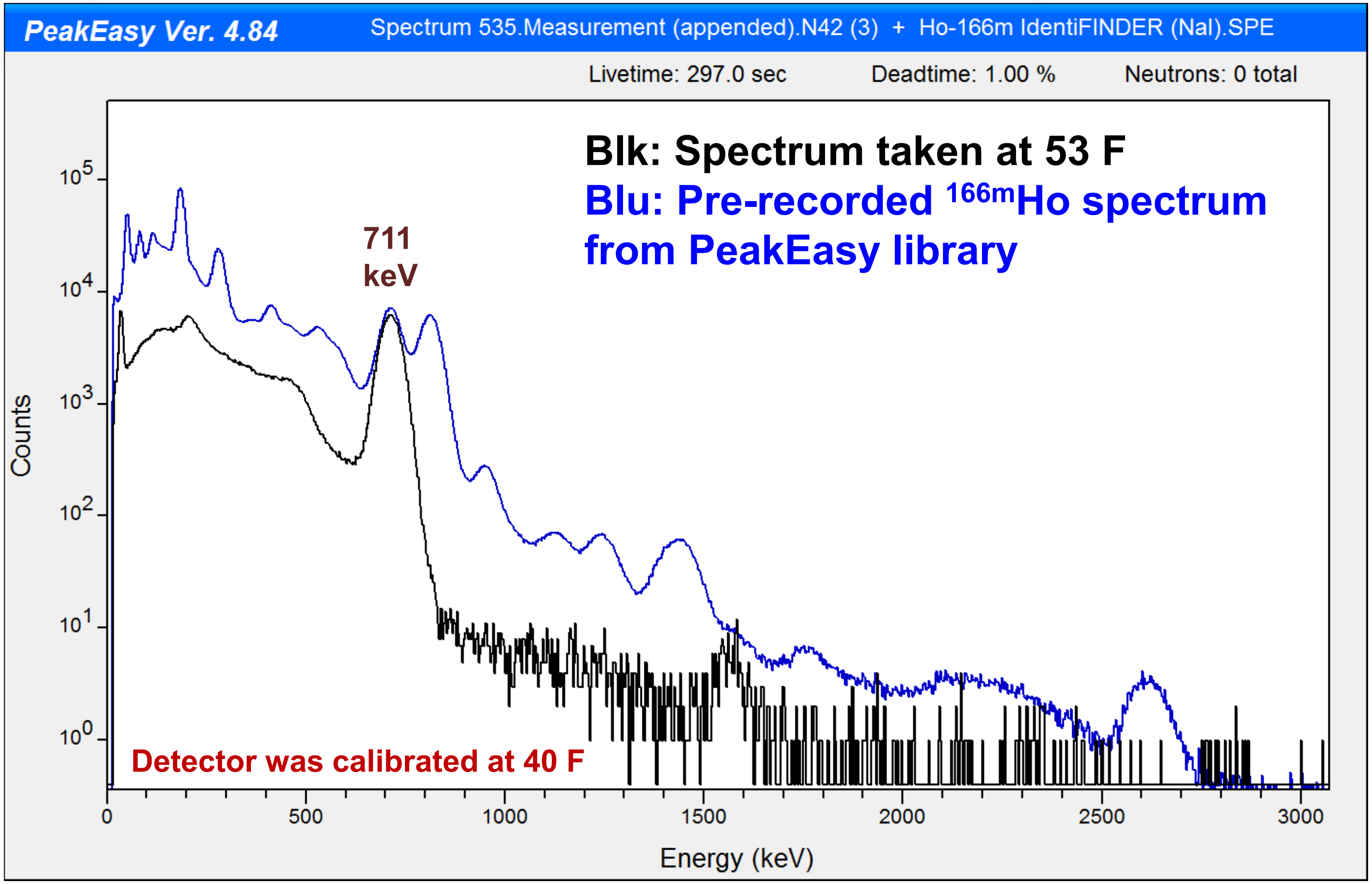
Nuclide ID results vs. Temperature



Spectrum at 41 F



Why ^{166m}Ho for the 53 F spectrum?

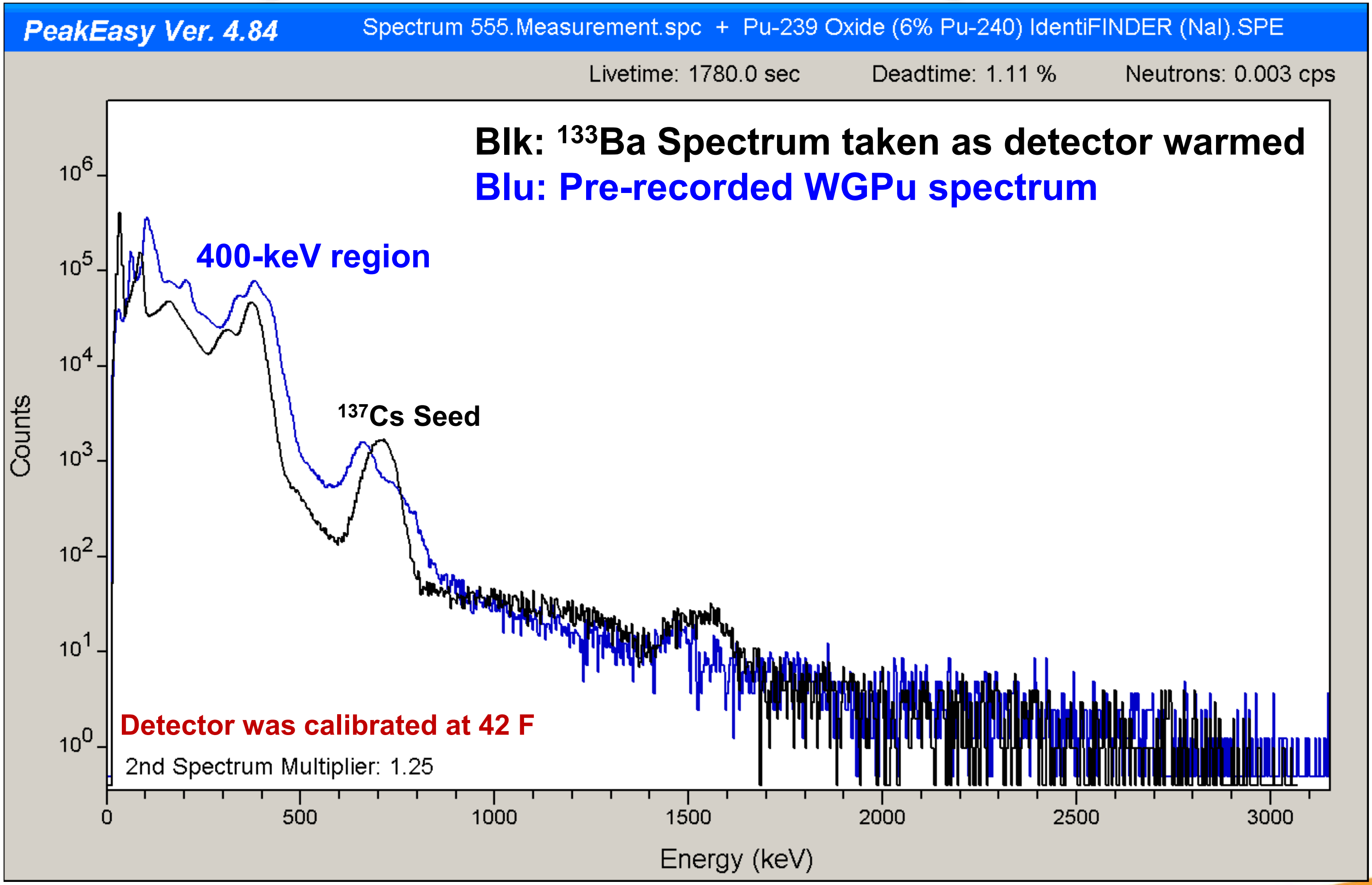


Nuclide ID Result for ^{133}Ba Measurement

For the 30-min spectrum taken while the detector was warming both ^{131}I and Plutonium were falsely identified with confidence values of 7 and 5 respectively.

Again, the detector was calibrated as soon as possible with an initial temperature measured as 42 F.

Why plutonium?



Thermal Variations Summary

- Drifting of the ^{137}Cs 662-keV peak occurred as the detector warmed.
- It appears that most of the drift occurred within the first 30-minutes of the warming process (for this thermal environment).
- Nuclide ID results significantly varied from the ground truth as expected
- ^{133}Ba measurement was done in a similar fashion but with a 30-minute integrated count as the detector warmed
- In each respective case the spectra still looked like the respective nuclides to the analyst's eye , but the instrument calibrated in one thermal environment was limited to identify nuclides as the environment changed.